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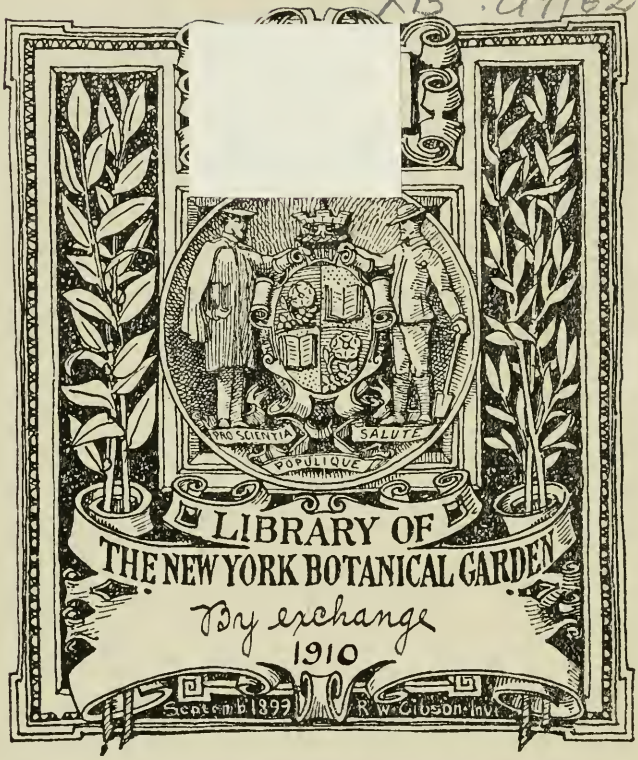
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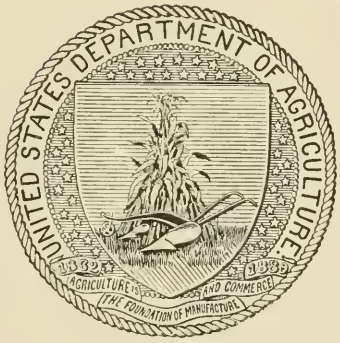

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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY—BULLETIN NO. 173.
B. T. GALLOWAY, *Chief of Bureau.*

SEASONAL NITRIFICATION AS INFLUENCED BY CROPS AND TILLAGE.

BY

C. A. JENSEN, AGRICULTURIST.

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BUREAU OF PLANT INDUSTRY—BULLETIN NO. 173.
B. T. GALLOWAY, *Chief of Bureau.*

SEASONAL NITRIFICATION AS INFLUENCED BY CROPS AND TILLAGE.

BY

C. A. JENSEN, AGRICULTURIST.

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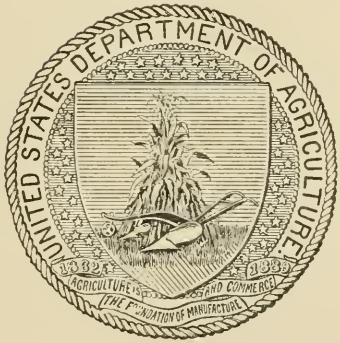

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SEASONAL NITRIFICATION AS INFLUENCED BY CROPS AND TILLAGE.

INTRODUCTION.

The attempt to bring the vast areas of prairie lands of the Great Plains under a profitable system of agriculture has been undertaken with renewed vigor during the last few years, both by the older settlers and by many new ones entering the Plains. These new settlers come mainly from the Middle West, where the climatic and soil conditions are very different from those in the newer areas where they settle. On the Great Plains the rainfall is likely to be too little rather than too much for good crop returns and, moreover, it does not always come at the time most convenient for the farmer; besides, the wind movement, especially in the spring, when the crops are being planted and when the surface of the soil is usually exposed in a rough condition, saps the soil of its moisture very rapidly.

Under such conditions it becomes necessary to control the quantity and the movement of the soil moisture, and as this moisture constitutes the plant nutritive solution it is obvious that not alone the absolute amounts of soil moisture present but the nutritive character of this solution become of importance, so that any cultural system inaugurated for the purposes of moisture conservation should be such that the quality as well as the quantity of the nutritive solution can be controlled.

It has often been observed that of two contiguous plats on the same type of soil one may yield considerably higher than the other, although the amount of soil moisture may be the same in both. In such cases it is often found that the properties of the nutritive solutions from the two plats are markedly different in their behavior toward plant growth, and often the history of the plats will show that the cultural methods have been different and that these may explain the differences found in the character of the soil moisture constituting the plant nutritive solution. The mere storing up, then, of soil moisture is not always sufficient for the purposes of good crop returns.

During the last few years a number of substations have been established by the Bureau of Plant Industry throughout the Great Plains

area for the purpose of finding out, if possible, the best methods of handling the prairie lands there so that profitable crop returns might be realized. At all of these stations a large number of rotations have been established, and other plats have been set aside for experiments with various methods of cultivation without regard to crop rotations.

In the spring of 1907 the writer was put in charge of the substation at Bellefourche, S. Dak., where experiments in dry-land agriculture were inaugurated. The station site was on virgin prairie lands, so nothing was done that year beyond breaking up and preparing land for use in 1908. In the spring of that year an elaborate series of rotation systems was established, and a large number of other plats were set aside for use in the studies of soil-moisture conservation by different methods of cultivation, the success of the methods being measured finally by the crop yields, though moisture determinations were made during the entire season.

The work to be described was done on some of the plats used for the purpose of trying out different cultural methods, it being thought that different crops and different tillage methods would influence the nutritive properties of the soil solution. Owing to the press of field duties and to the inconvenient location of the station as regards supplies, it was found necessary to limit the laboratory work to a study of the natural activity of nitrification in the soil as measured by determinations of nitrates, nitrites, and ammonia in three plats receiving different treatments and bearing different crops.

The literature on nitrifying organisms and on nitrification is very voluminous, and while the author does not by any means claim to have read it all, it is believed that most references which have any direct bearing on the present subject matter have been cited. In no case was there found reported work on nitrification in the field as influenced by crops and tillage that had been carried on continuously throughout the crop season. The few references found which might have a bearing were generally reports on work carried on in humid regions or in the laboratory, the conclusions of which could hardly be extended to the semiarid regions. Much of the literature, however, was helpful in formulating suggestions explaining the phenomena found.

DESCRIPTION OF THE SOIL IN WHICH THE EXPERIMENTS WERE CONDUCTED.

The soil of the station and of the surrounding country is known as "gumbo" and is a heavy, black or gray, clay loam to a depth of 2 to 3 feet, and below this depth heavy clay usually occurs, extending to 6 feet or deeper, overlying the partially disintegrated cretaceous shale which is the geological formation of the whole surrounding country.

FIELD HISTORY OF THE PLATS.

The prairie sod, covered originally with western wheat-grass (*Agropyron occidentale*), buffalo grass (*Bulbilis dactyloides*), and gramma (*Bouteloua oligostachya*), with minor quantities of sedges (*Carex filifolia* and *C. stenophylla*) and other grasses, together with a few vetches, was broken in the spring of 1907 to a depth of about 3 to 4 inches, backset (replowed) in the fall of 1907 to a depth of about 5 inches, and left open until the spring of 1908, when it was disked and harrowed until a good seed bed was secured. Such was the treatment of the spring-wheat plat and the corn plat used in the work. A plat reserved for summer-fallow used in this work was spring-plowed to a depth of about 8 inches, smoothed with a disk, and harrowed. This plat was cultivated during the summer to keep weeds down and to conserve the moisture.

The determinations on the corn plat were not begun as early as on the wheat and fallow plats. As this plat was not planted as early as the wheat plat, it was taken for granted that the soil conditions would be the same as those of the fallow plat until the time of planting the corn.

METHODS OF MAKING DETERMINATIONS.

The chemical methods used were those described in Bulletin No. 31 of the Bureau of Soils. The soil samples were collected in duplicate from 6-inch layers to a depth of 2 feet—that is, in 0 to 6, 6 to 12, 12 to 18, and 18 to 24 inch depths—and the two cores from each soil layer made into a composite sample. The samples as bored up with the auger were transferred to air-tight tin cans, taken immediately to the laboratory, weighed, dried in an oven at a temperature of about 100° C., and again weighed. In preparing the solution it was found necessary to adopt this drying method in order to insure thorough mixing of the soil and the water, as it was practically impossible to break down the moist gumbo pieces directly. The ratio of soil to water was 1 to 5 (100 grams of soil to 500 c. c. of water). After drying, the soil particles readily broke down and after thorough stirring in the water would settle out quite clear in about 20 to 30 minutes. The supernatant liquid was then poured into Chamberland filters and filtered. Such a procedure of drying the soil could, of course, not be employed were determinations to be made of such soil elements as are derived directly from the soil minerals, as potassium, phosphoric acid, etc., but owing to the origin and nature of the nitrates and nitrites in the soil the solubility is not increased; neither is it likely that decomposition of a disturbing nature would take place. Experiments were made to compare the two methods of obtaining the

soil solutions from soil that was first dried and from undried samples direct from the field. The results agreed within the limits of experimental error, and as better mixing was possible by using the dried samples this procedure was an advantage.

The determination of nitrates under ideal conditions does not present any serious difficulty if the procedure is carefully followed out and precaution against errors observed. As is well known, however, difficulties are likely to be encountered when nitrates are to be determined in soil extracts, especially if the extract is highly colored with soluble organic matter or if it contains considerable soluble inorganic salts, especially chlorids. There are thus three main sources of error in nitrate determination in a soil extract: Foreign organic color, which is superimposed on the yellow color developed on nitration of the phenoldisulphonic acid, which renders the colorimetric reading more difficult; the soluble organic matter may be acted upon by the nitrates, or possibly by the acid, thus introducing a chemical error; the presence of considerable amounts of alkali salts, of which chlorids seem to be the most serious ones.

The soil extract obtained in the work here reported did not contain enough chlorids to cause error, as the amounts were too small to measure accurately by means of titration; only traces were ever observed, and frequently none at all.

The errors which might be introduced because of the presence of soluble organic matter are believed to be too small to seriously consider, as the only soil samples which gave appreciable organic colors were those from the fallow plat, and no serious difficulty was encountered in making the colorimetric readings of these extracts, the organic color being of quite a different shade from the yellow color due to nitration. The error which may have been introduced through the chemical disturbance of the organic matter was neglected, it being considered too small to be of serious consequence; as stated above, the organic color was not strong. All points considered, it was decided that under the circumstances and conditions less error would be involved in using the solutions directly as obtained than by trying to free them of organic matter by oxidation or reduction.

It should be kept in mind that the chief value of the results obtained lies in their relativity more than in the absolute amounts found. This weekly relation of the amounts of nitrates in the various soil layers in the various plats could not be seriously disturbed by any slight error which might possibly have been introduced because of the presence of soluble organic matter in the soil extracts.

It has been quite well made out that no appreciable error was introduced in quickly drying the soil samples in the oven at 100° C.

This was established at the time and has been also found in the bacteriological laboratory of this Bureau to be a safe procedure for purposes of comparison.

A comparison of results obtained by the various methods of extraction is given in Table I.

TABLE I.—*Nitrites, nitrates, and ammonia found in dry soil treated in various ways.*

Soil treatment.	Parts per million in dry soil.		
	Nitrites (NO_2).	Ammonia (NH_3).	Nitrates (NO_3).
Fresh untreated soil, using undistilled water	0.55	1.5	26.7
Fresh untreated soil, using distilled water	.55	.8	22.2
Fresh untreated soil plus chloroform, using undistilled water	.55	2.5	22.2
Fresh untreated soil plus chloroform, using distilled water	.55	2.0	25.0
Soil dried in oven at 100° C	.55	3.33	36.4

The oven-dried sample in this case gave a higher proportion of ammonia and nitrates than the other samples. It is possible, though, that nitrification went on to some extent before the sample was properly dried, as the gasoline drying oven was troublesome, this being its first use. The soil sample was in the oven most of the day before the trouble with the burner was located, and it was warmed most of the day without quickly drying.

The following set was run through the next day, a soil being used that had been carefully prepared for a winter-wheat seed bed the previous year but which had not been planted:

TABLE II.—*Nitrites, nitrates, and ammonia found in dry soil from a seed bed treated in various ways.*

Soil treatment.	Parts per million in dry soil.		
	Nitrites (NO_2).	Ammonia (NH_3).	Nitrates (NO_3).
Fresh untreated soil immediately extracted	0.28	.....	133.3
Fresh soil plus chloroform and immediately extracted	.28	.....	133.3
Fresh soil after three hours' treatment with chloroform and dried quickly at 103° C	.20	.....	133.3
Fresh soil dried immediately in oven without being treated with chloroform	.33	.....	133.3

The ammonia was not read, as the solution contained foreign coloring matter. These and the previous results give an idea of the limits of experimental error. The standard solutions used for comparison in the colorimeter were made up fresh on the day they were used, and all readings were made within a few hours. The nitrite reagents were kept separate and small portions mixed as needed for use.

The systematic determinations were begun April 27, and from then until July 31, about ten days after harvest, the determinations were made once a week.

DISCUSSION OF RESULTS OF DETERMINATIONS.

NITRATES IN THE FALLOW PLAT.

Figure 1 shows the parts per million of nitrates calculated for the oven-dried soil in each 6-inch layer in the fallow plat from April 27 to July 31 and the precipitation for the same period. About 1 inch of rain had fallen from April 1 to April 27. The weekly periods are laid off on the abscissa, and the parts per million of nitrates on the ordinate. The precipitation scale is on the right-hand side of the figure.

The first two sets of determinations show decreasing amounts of nitrates from the surface 6-inch layer downward, the second foot con-

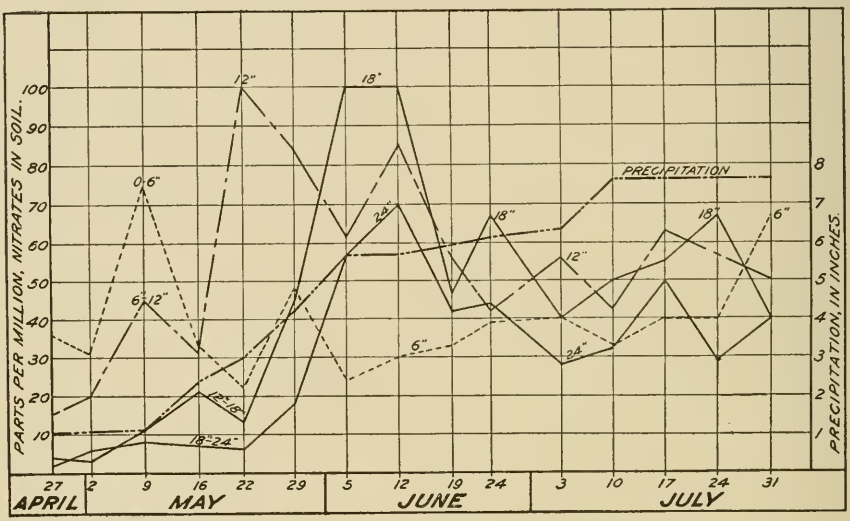

FIG. 1.—Diagram showing the parts per million of water-soluble nitrates in dry soil in the fallow plat in each 6-inch soil layer to a depth of 2 feet; also precipitation curve.

taining very small amounts. There were no marked changes until May 9, when the surface 6 inches of soil showed a considerable increase in nitrates, and it is also seen that at this time this soil layer contained a maximum amount of water-soluble nitrates. The nitrates in the second layer, 6 to 12 inches, had more than doubled since the week before, but there were no considerable changes in the lowest two layers. By the next week, May 16, the surface 6 inches of soil had decreased about forty parts per million, and there was also a decrease in the 6 to 12 inch layer. By the next week, on May 22, a marked increase in the amount of nitrates is evident in the 12-inch layer, it having increased about seventy parts per million during six days, and the surface 6-inch layer had decreased about ten parts per million. At this date the 12-inch layer contained the maximum quantity of

nitrates. Up to this time there were no great changes in the nitrates in the 18 and 24 inch layers, but from May 22 to June 5 these layers accumulated considerable amounts, and on the latter date the 18-inch layer contained the maximum, which remained constant until the next week, June 12. In the mean time, the 24-inch layer accumulated considerable quantities of nitrates, reaching its maximum on June 12.

It will be noticed in general that from April 27 to June 5 the maximum amount of water-soluble nitrates shifted every two weeks to the next lower layer and that once any layer had accumulated a maximum it decreased and in general never again contained as large amounts as the maximum of the next lower layer, which was reached at a later date.

From June 12 to June 19 there was an interesting change, in that every soil layer which had recently been actively accumulating nitrates suddenly showed a marked decrease in amounts of water-soluble nitrates, and all of the layers on June 19 contained nearly the same amount of nitrates. The upper 6-inch layer did not show any such decrease, the reason for which will be discussed later on. From June 19 till July 31 there were no regular changes, all of the curves zigzagging irregularly.

In view of the marked increases in the amount of nitrates in the 18 to 24 inch layer, it is to be regretted that determinations were not made in the third foot also, but time did not permit the increased work. The 18 to 24 inch layer never contained a maximum amount of nitrates in comparison with the other layers, but the results certainly indicate that nitrification is quite active at a depth below 2 feet in these prairie soils when they are brought under cultivation. Bazarewski[a] found very few nitrifying bacteria, however, at a depth of 50 centimeters and reports that they were "plentiful at a depth of 10 centimeters." It will be noticed from figure 1 that the 18 to 24 inch soil layer accumulated as much water-soluble nitrate as did the 0 to 6 inch layer, so nitrifying organisms are presumably active in this prairie soil to a depth considerably greater than 2 feet. Hunt[b] likewise reports that nitrification took place to but a small extent below a depth of 2 feet, and the figures given by him show that under the conditions discussed nitrification was not very active in even the second foot.

In this connection it may be of interest to mention that the unbroken prairie "gumbo" never becomes moistened deeper than about 8 to 10 inches even after the heaviest rains. Cultivation,

[a] Bazarewski, L. von. Nitrification and Denitrification in Soils. Reviewed in Experiment Station Record, vol. 21, no. 1, July, 1909, pp. 20–21.

[b] Hunt, T. F. The Importance of Nitrogen in the Growth of Plants. Bulletin 247, New York (Cornell) Agricultural Experiment Station.

however, soon results in the soil becoming moistened deeper than 6 feet within one year after breaking the sod and cultivating the soil. It is fair to assume, therefore, that nitrification in the unbroken land can not take place to any great extent much below a depth of 1 foot.

NITRATES IN THE SPRING-WHEAT PLAT.

Figure 2 shows the results obtained from determinations made on the spring-wheat plat. These determinations were not begun until May 9, but a vertical section made in figure 1 on May 9 will show that the order is about the same at this point on both figures.

Figure 2 does not contain the precipitation curve, but in addition to the curves showing the amounts of nitrates in the 6-inch soil layers,

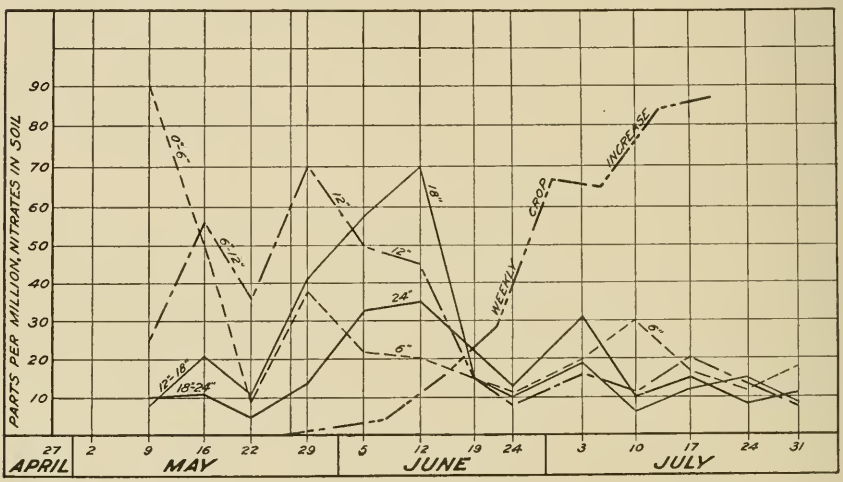

FIG. 2.—Diagram showing the parts per million of water-soluble nitrates in dry soil in the spring-wheat plat in each 6-inch soil layer to a depth of 2 feet; also weekly increase of wheat plants.

it shows the curve representing the weekly increase in the dry weight of the wheat plants. The increase was determined each week by cutting four 3-foot squares, two near each end of the 2 by 8 rod plat, both green and air-dry weights being obtained. Only the dry weights are platted in the figure.

A comparison of figure 1 and figure 2 shows the same general fact, namely, that the maximum amount of water-soluble nitrates in any soil layer is shifted every two weeks to the next lower layer. The detailed variations are about the same in the two plats, but there is one general difference—the date of the maximum accumulation of nitrates in the respective soil layers in the two plats is shifted one week forward in the case of the spring-wheat plat—that is, each of the 6, 12, and 18 inch layers, respectively, attained its maximum

accumulation of water-soluble nitrates just one week later in the wheat plat than in the fallow plat. It will be remembered that it was stated that the fallow plat was plowed to a depth of about 8 inches in the spring of 1908 and that the wheat plat had not been plowed since being backset in the previous fall to about 5 inches deep. There was thus a difference in the mechanical condition of the two plats; the summer-fallow plat being more open and stirred to a greater depth, there was presumably a more rapid access of air, and in consequence a more rapid rise in temperature. Hunt[a] also found that early plowing promoted nitrification more rapidly than late plowing, and presumably early plowing would promote nitrification more rapidly than no plowing at all.

It was expected that some information would be obtained in regard to the rate at which the growing wheat plants removed the nitrates from the different soil layers, that being one of the main points sought for in the work. As a matter of fact, it will be noticed that the curves of the two figures are so much alike in the general trend that were they not scaled or labeled in any way it would be difficult to say which figure represented the fallow plat and which the wheat plat. The shifting of the dates of the maximum accumulation of nitrates in the individual soil layers one week back in the case of the fallow plat might be explained by the difference in the tillage. By using the fallow plat as a check on the wheat plat, which is really what it is, it will be noticed that aside from this shifting already mentioned the only general differences are the smaller amounts of nitrates found in the wheat plat and that after June 19, when the general decrease in nitrates took place—as in the fallow plat—the nitrates in each soil layer in the wheat plat were more constant in both total amounts and amplitude of variation. Had the results on the fallow plat not been obtained as a check on the results obtained on the wheat plat, it might have been supposed that during the time immediately following June 12, when the wheat plants were making rapid increase in growth, the crop was removing nitrates much more rapidly than they were being formed. Even thus one would hardly expect the nitrates to be removed so spontaneously and almost completely from each 6-inch soil layer. One can not, then, from the amounts of water-soluble nitrates found, determine the soil layers in which the wheat roots were feeding most rapidly or demonstrate any progressive downward ranging of the roots as the season advanced. The apparent "removal" of the nitrates from the soil is due, then, to some other factor than the presence of the crop.

Even after June 19, when the marked decrease in the amounts of water-soluble nitrates occurred, there is no consistent correlation

[a] Hunt, T. F., loc. cit.

between the weekly increase in the dry weight of the wheat crop and the amounts of nitrates present. On the contrary, from June 24 to July 3 there was a general increase in the amounts of nitrates corresponding to the greatest weekly increase in the growing crop.

COMPARISON OF NITRATES IN FALLOW, SPRING-WHEAT, AND CORN PLATS.

Figure 3 shows the amounts of nitrates—averages of the four 6-inch soil layers—found during the season in the wheat plat, the fallow plat, and the corn plat; also the precipitation curve and the weekly crop-increase curve. It is to be regretted that the same amount of data could not have been obtained from the corn plat as from the wheat plat, but time did not permit. Nothing much can

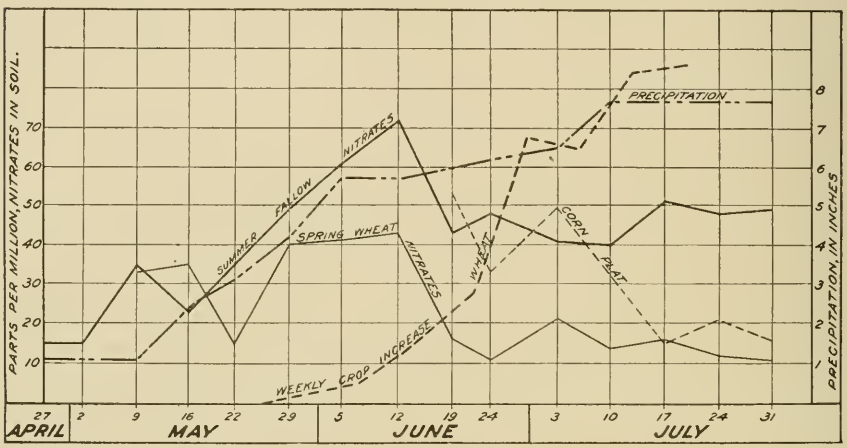

FIG. 3.—Diagram showing the average parts per million of water-soluble nitrates in dry soil to a depth of 2 feet in the summer-fallow, spring-wheat, and corn plats; also weekly increase of wheat plants and precipitation curve.

be said about this curve beyond the statement that the rapid decrease in nitrates corresponds quite closely to the period of most rapid growth of the corn as recorded in the notes at the time.

The corn plat had evidently accumulated quite large amounts of nitrates before the plants were large enough to materially draw upon these salts, for the corn curve shows that on June 19 the accumulation of nitrates in the corn plat had reached about the same point as that in the fallow plat. The direction of the corn-plat curve from June 19 to June 24 also suggests the general drop found in the fallow and wheat plat curves. As the corn was not planted until May 7, the plat was evidently in a state of summer fallow until determinations were begun. During the most active growing period of the corn these plants evidently reduced the amounts of nitrates to as low a

content as did the wheat plants in the wheat plat. Apparently the corn plants were as fond of the nitrates as were the wheat plants. The general field observation that a corn crop renders the ground more productive for grain than a previous grain crop is apparently not due to the leaving of greater amounts of nitrates in the soil.

WITHDRAWAL OF NITRATES BY CORN ROOTS.

As already mentioned, the general decrease in the amounts of water-soluble nitrates in both the fallow and the wheat plats masked the effect of any progressive withdrawal of the nitrates by the wheat-plant roots in the successive soil layers. In the case of the corn plat, however, there was the advantage of the fact that the nitrates had already been accumulated, and so the corn offered an opportunity for observing the removal of nitrates from the various soil layers as the

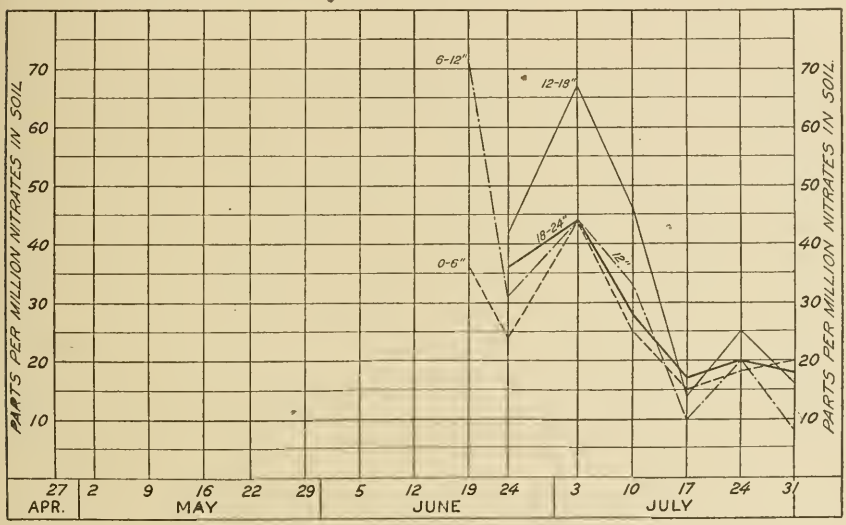

FIG. 4.—Diagram showing the parts per million of water-soluble nitrates in dry soil in each 6-inch soil layer in the corn plat to a depth of 2 feet.

season progressed. Figure 4 shows the probable effect of the feeding of the corn roots and indicates that the surface 6-inch layer early lost considerable amounts of nitrates and that very shortly thereafter the 12-inch layer was drawn upon most heavily. From July 3 to July 17 the corn plants made their most rapid growth, and the curves also show that at this period the nitrates were most heavily drawn upon. The 18-inch layer contained most nitrates and lost most. All of the layers to a depth of 2 feet were probably reduced to the limit of the powers of the corn roots to withdraw nitrates from this heavy soil.

The curves in figure 4 also show variations in the activity of nitrification, especially an increase from June 24 to July 3, but the

progressive downward feeding of the corn roots seems clearly shown. The characteristic manner of surface feeding of corn roots would early draw upon the plant food in the surface soil, as indicated in figure 4 by the curves of the 6 and 12 inch layers. The soil samples, however, were taken not between the corn rows, where the lateral roots only were abundant, but as near the corn plant as they could be taken, not more than 3 or 4 inches away. Such sampling would encounter the primary roots of the corn, as well as penetrate the soil area in which the lateral roots were feeding most actively, and it seems probable that the reduction of the amounts of nitrates in the 18 and 24 inch layers was due to the penetration of these primary roots to that depth. This would account for the tardy removal at the lower depth, as the primary roots would be longer in reaching these lower layers. The moisture determinations showed that the moisture was being removed quite rapidly from the 18 and 24 inch soil layers at the same time.

The most striking feature about figure 3 is the general parallelism of the nitrate curve of the wheat plat with the nitrate curve of the fallow plat. The seven-day lagging of the maxima in the wheat plat is not, however, as clearly shown here as in figures 1 and 2, but is evident in the early part of the season. The only other point of difference in the two curves is in the period from May 29 to June 12, during which time the summer-fallow plat steadily accumulated nitrates, while there was a bare increase in these salts in the wheat plat. This is the period during which the fallow plat laid in its increased stock of water-soluble nitrates, and from June 12 on there is a constant difference of about twenty to thirty-five parts per million in favor of fallowing. It is probable that this difference represents in general the continuous amount of soluble nitrates used up by the plants. It is, however, also likely that had more nitrates been formed the plants would have used them and that the curves represent in a general way the minimum amount to which the corn and wheat roots can reduce the nitrates in this heavy soil. Traps [a] found that the nitrogen content of crops was increased with an increased nitrifying activity in the soil.

In figure 3 no close relation is evident between the weekly crop-increase curve and the decrease in the nitrates, using the fallow curve as a check.

RELATION OF NITRIFICATION TO FIELD FACTORS.

The nitrification in the soil depending, as it does, on so many factors—temperature, moisture, aeration, organic matter, kind of crop, cultivation, etc.—it is difficult in the field to run down the

[a] Traps, G. S. Bulletin 106, Texas Agricultural Experiment Station, p. 4.

specific physical or chemical factors most influential in the promoting of the formation of nitrates in a given soil type. An attempt was made to correlate the variations in and the amounts of the nitrates found during the season with some of the factors known to influence their formation. As some of the most important ones from a chemical or bacteriological standpoint could not be taken up at the time the attempt at correlation had to be confined to a consideration of some of the physical factors. As, however, the soil of the different plats was similar and probably as nearly uniform as it is possible to obtain soil in different plats, and, furthermore, as the past history of the plats was exactly the same up to the time of beginning the work, it is not likely that there were any fundamental chemical or bacteriological differences in the plats at the time of planting. The wheat and corn plats were adjacent and were separated from the fallow plat by only 6 rods, and certainly no differences were apparent. Continuous air-temperature records were kept by means of a thermograph,

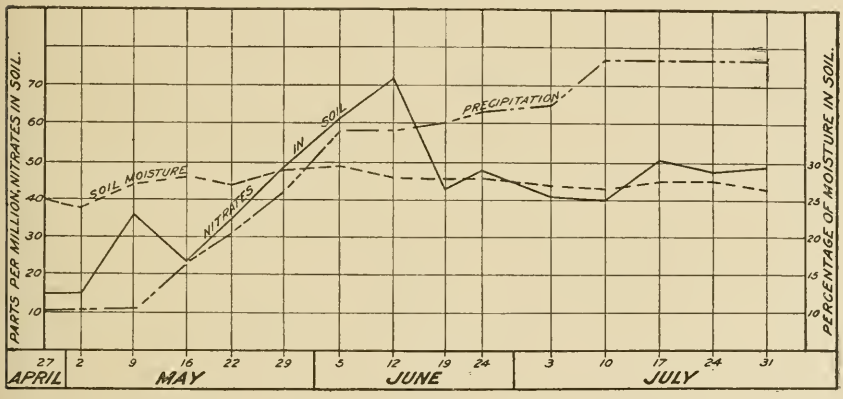

FIG. 5.—Diagram showing the average parts per million of water-soluble nitrates in dry soil in the fallow plat to a depth of 2 feet; also soil-moisture curve and precipitation curve.

but no evident relation could be obtained between the variations in amounts of nitrates and in temperature, whether the mean maximum, mean minimum, or general mean temperature was considered.

Figure 5 shows the curve of average amounts of nitrates to a depth of 2 feet in the fallow plat, the average soil-moisture curve to the same depth, and the precipitation curve. It is evident that neither the soil-moisture curve nor the precipitation curve shows any close agreement with the nitrate curve. The moisture curve is nearly straight, varying only from 24 to 29 per cent during the whole season. The other two curves parallel from June 19 to the end of the season, but as the formation of nitrates had already taken place and as the amounts thereafter remained constant, it is likely that this agreement is only incidental. It might be mentioned, incidentally, that the

mean temperature of the air did not reach nearly its maximum until some time later than June 19; in fact, the maximum temperature occurred in September.

In figure 6, which gives the corresponding data obtained on the wheat plat, there is a closer relation between the moisture and the nitrate curves, but as the growing crop has removed much of the moisture and the nitrates from the soil it is apparent that no close causal relationship could be insisted on in this case either. There is, on the other hand, a close agreement between the moisture curve and the weekly crop-increase curve. The hygroscopic coefficient for this soil is very high (about 12 per cent), and judging from the general appearance of the crop and of the soil at the time it is likely that the moisture curve from the first part of July represents about the minimum to which the wheat plants could reduce the moisture content of the soil, and the same holds true in regard to the nitrate

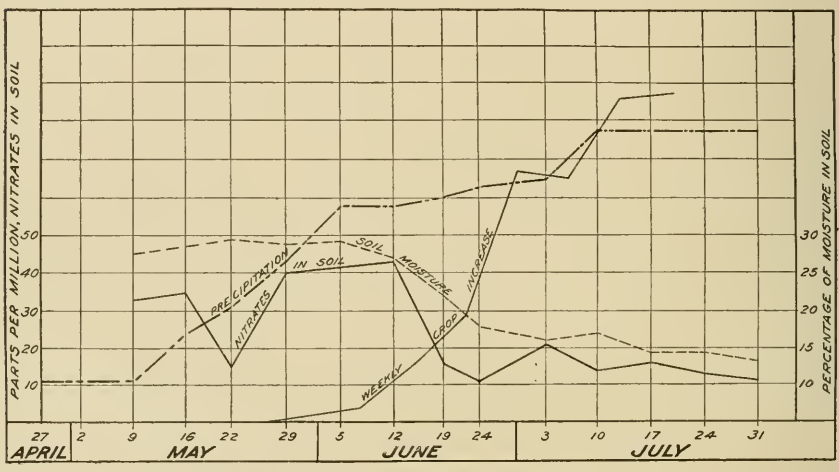

FIG. 6.—Diagram showing the average parts per million of water-soluble nitrates in dry soil to a depth of 2 feet in the spring-wheat plat; also soil-moisture, precipitation, and weekly crop-increase curves.

curve, as mentioned earlier. This same removal of moisture would, of course, also check nitrification, so both this and the plant feeding would keep the nitrates from increasing.

Figure 7 brings out more clearly than figures 1 and 2 the phenomenon of the general parallelism in the maximum nitrate accumulation in the individual soil layers in the wheat and fallow plats. This figure does not show the absolute amounts of nitrates found in the soil, but shows simply the period during which the respective 6-inch soil layers in the fallow and wheat plats contained an amount of nitrates greater than any other 6-inch layer. It will be noticed that there is a very close agreement between the two plats in the depth

at which nitrates were most actively accumulating at different periods and that other factors than cropping evidently determine the seasonal activity of nitrification.

THE DISAPPEARANCE OF NITRATES.

Glancing again at figures 1 and 2 it would naturally be asked what became of the water-soluble nitrates in the individual 6-inch soil layers after accumulation had reached a maximum, and why the seasonal shifting of the maximum amount of nitrates has such a distinct downward movement. It would be expected that the rainfall would tend to wash down the nitrates along with other salts, and such probably did take place to some extent. Selecting the week from May 9 to May 16, in figure 2, there would seem to have been

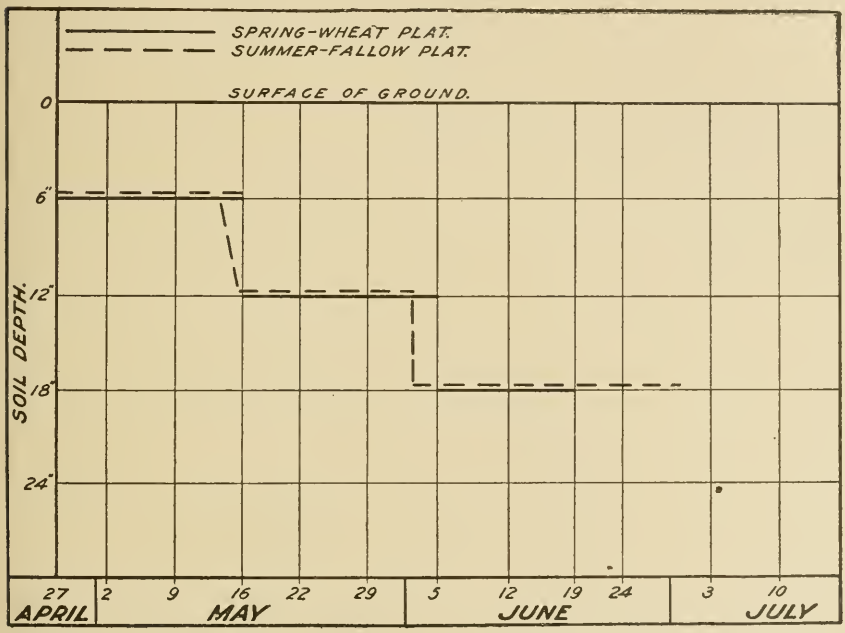

FIG. 7.—Diagram showing the time and location of the maximum amount of nitrates in the wheat and fallow plats.

such a movement from the surface layer to the 12-inch layer. The rainfall for that week was 1.25 inches. This is the only instance, however, in the two figures which shows the plausibility of such an explanation of the apparent downward "movement" of the nitrates. Inspecting figure 1, where no growing crop complicates the results, it would even appear that the rainfall had the opposite effect, as, for instance, during the period from May 22 to May 29. The effect seen there could not be explained by the washing down of the nitrates by the rains, as there was an increase in nitrates in all of the soil layers

except the 12-inch layer during that week. The same point is brought out during the period from June 5 to June 12, there being no rainfall at all to wash down the nitrates from the surface into the 12, 18, and 24 inch layers. And, finally, no such explanation can be given for the sudden drop in amounts of nitrates during the period from June 12 to June 19, when there was practically no rain.

DENITRIFICATION.

At the beginning of the work denitrification was expected to become an obvious factor in affecting the seasonal changes of nitrates in the soil, and ammonification was also expected to become of measurable importance; accordingly, determinations of nitrites and ammonia were made. Neither of these activities, however, assumed any importance at all during any part of the season so far as the analyses brought out, and, accordingly, toward the end of the season ammonia and nitrite determinations were not regularly made—sufficiently often, however (usually every other week), to know the amounts present of these compounds.

No conveniences were at hand for making ammonia determinations directly on the fresh soil, and this is obviously the best way of determining these compounds. The determination of the water-soluble ammonium compounds could not be expected to give reliable data. That ammonia may have been formed in larger amounts than would be suggested by the quantities found during the season would appear from the work of Stevens and Withers,[a] who state that in some soils "nitrification proceeds as rapidly as ammonification, converting the ammonia to nitrate as fast as it is rendered available by the ammonifying organisms."

The amounts of nitrites found varied during the whole season from nothing to 1.8 parts per million in the dry soil. There was no regularity in even these small amounts, one week traces only or none at all being found and the next week traces to 1.8 parts per million. The same irregularities held true in the individual soil layers. The usual amounts of nitrites were from 0.1 to 0.3 part per million, and one single sample—from the 6-inch layer in the wheat plat, on May 22—had 6 parts per million, the only nitrite determination made that exceeded 1.8 parts per million at any time during the season.

The determinations likewise showed the presence of but small quantities of ammonia per million parts of dry soil, but in this case there was a slight decrease toward the end of the season. During the earlier part of the season, the amounts found averaged 6 to 8 parts

[a] Stevens, F. L., Withers, W. A., et al. Centralblatt für Bakteriologie, Parasitenkunde und Infektionskrankheiten, pt. 2, 1909, p. 23; abstracted in Experiment Station Record, vol. 21, no. 2, 1909, pp. 118-119.

of ammonia per million and toward the end of the season the amounts fell to about 3.6 to 4.7 parts per million. No such gradual decrease in amounts of nitrites toward the end of the season occurred. The variations in the quantities of ammonia and of nitrites in the individual soil layers were apparently not then sufficient to account for the marked and general and consistent changes observed in the case of the nitrates.

It may be remarked that although the soil is heavy in texture and likely to compact under bad treatment, the soil on the plats was quite loose and open, it being the first year after breaking. Also, toward the middle of summer the soils cracked quite freely, so that there was fair opportunity for soil aeration all season, and, as the precipitation curve will show, there was no trouble with water-logging of the soil. All conditions considered, it is apparent that conditions were not extremely favorable for active denitrification.

SEASONAL VARIATIONS IN NITRIFICATION.

Referring again briefly to all of the figures, one is struck by the remarkable uniformity of direction of all the curves, especially in figures 1, 2, and 3. The facts that the same general variations exist in all cases and that denitrification is probably not responsible for the nitrate changes point to a general seasonal phenomenon which is affected in degree but not in kind by the presence of the growing crops.

It must be kept in mind that the nitrates found were those soluble in water and that the curves thus represent only the water-soluble nitrates. It would appear that nitrification began earliest in the surface layer of the soil and that the maximum activity of this process gradually extended downward into the successively lower 6-inch layers and reached its maximum in any one layer in general at a period of about two weeks later than in the next 6-inch layer above. In other words, conditions of temperature, aeration, etc., were favorable for nitrification in the surface layer earliest, as would of course be expected, and these favorable conditions obtained later in the lower soil layers. By June 12 these requisite conditions had in general reached their optimum throughout the 2-foot soil section studied, and it might well be conceived that the physiological activity of the bacterial flora necessary for nitrification reached its maximum in the comparatively short period of about two or three weeks in each soil layer after the conditions had once become most favorable and that the general "crop" of nitrifying bacteria matured by the middle of June.

Under this interpretation it would be inferred that the nitrifying bacteria had an active growing season, so to speak, of two to three

weeks after favorable climatic conditions had been established and that after this period of growth they underwent a resting period, or at least their physiological activity was much reduced, just as is the case with an annual flora of higher plants. From this explanation one would expect that their general activity would be more intense and begin earlier in the fallow plat than in the wheat plat, as the former was spring-plowed to a good depth, while the latter was not so treated—and this is the case. As already noted, the maximum nitrate content in the respective soil layers occurred in general about one week earlier in the fallow than in the wheat plat, but the general "maturity of the crop," to continue the analogy of the higher flora, was effected at about the same time in the two instances, viz, about June 19. This seasonal decrease in nitrification may also be caused by a decrease in food readily available for the nitrifying organisms. Whether the seasonal variation in amounts of nitrates is due to periodicity of the activity of the nitrifying organisms in the soil, unaffected by any climatic or food factor, or whether it is due to lack of sufficient food for continued activity would be hard to decide from the various curves. As somewhat similar variations may be obtained in the laboratory under controlled food conditions, this factor must be kept in mind. Schneider[a] found that the fixation of nitrogen in the soil was greatly increased by the addition of organic food, as also by the addition of potassium phosphate and of lime; and Bazarewski[b] found that the addition of small amounts of organic food promoted nitrification, but that the addition of larger amounts decreased the activity of the organisms.

Notwithstanding the fact that neither nitrites nor ammonia were ever found in sufficient amounts to account for the actual decrease in amounts of nitrates, other organisms active in the production of these compounds may conceivably have increased vegetatively at the expense of the nitrates already present. Whether the food supply itself could be entirely responsible for the variations in the amounts of nitrates it would be hard to decide, but certainly the prairie soil in question is considered quite fertile so far as the ordinary farm crops are concerned, and the plats on which these determinations were made had never been cropped before.

That this rather definite and comparatively short seasonal period of activity of nitrification has not been limited by lack of moisture in the soil would seem to be indicated by the moisture conditions in the summer-fallow plat. The drying up of the soil in the wheat plat, due to the demands made upon the moisture by the plants, would of

[a] Schneider, P. Landwirtschaftliche Jahrbücher, vol. 35, sup. 4, 1906, pp. 63–83; abstract in Experiment Station Record, vol. 18, no. 8, April, 1907, p. 722.

[b] Bazarewski, L. von. Nitrification and Denitrification in Soils. Reviewed in Experiment Station Record, vol. 21, no. 1, July, 1909, pp. 20–21.

itself inhibit nitrification, just as excessive dryness would check the growth of any other plant.

It seems evident, therefore, that the decrease in amounts of nitrates can not be wholly explained by either moisture content of the soil, denitrification, ammonification, or temperature. A shortage in organic food supply may have been one of the principal causes, but it is also possible that the amounts of nitrates accumulated by the nitrifying organisms would inhibit further increase in these salts. Instances of such inhibition are not uncommon in the case of other bacteria and fungi. It is also within the province of possibility that the nitrifying organisms may have accumulated compounds as by-products other than nitrates and that these compounds might have checked any otherwise possible increase in amounts of nitrates. Even when all these factors are considered there would appear to be a rhythmic periodicity of nitrifying activity during the season due to some unknown property of the bacteria.

CHANGE OF WATER-SOLUBLE NITRATES TO ALBUMINOID NITROGEN.

The disappearance of the water-soluble nitrates does not by any means indicate that the nitrogen was actually lost from the soil, but that it was perhaps converted into albuminoid nitrogen by other groups of bacteria. It is quite conceivable that the food requirements might be sufficiently different for the two groups to permit a considerable decrease in the activity of one group and at the same time increase the activity of another group. It may very well be that the artificial application of a food supply suitable for use by the nitrifying organisms would again increase their activity to a point beyond that which they formerly had reached. It is likely that had water-insoluble nitrogen been determined in the same soil series, no general decrease would have been found in this from June 12 to June 19; on the contrary, there would probably have been an increase. In this connection it may be mentioned that Montanari[a] found least amounts of "nitric nitrogen" in February, March, and June, and most in July and August. He found that plats growing wheat, rape, and corn contained more nitrates in the lower stratum (10 to 20 centimeters) than in the upper (0 to 10 centimeters); on a plat growing Medicago, however, this relationship was reversed. This accumulation of the (probably) albuminoid nitrogen would very possibly be of use to plants the following spring and would simply be held in reserve in the soil and either break down into readily water-soluble forms or in other ways become available for use by higher plants. Whitson,

[a] Montanari, C. Quantity of Nitric Nitrogen in Soils Variously Cultivated. Le Stazioni Sperimentali Agrari Italiane, vol. 41, 1908; abstract in Experiment Station Record, vol. 20, no. 8, March, 1909.

Stoddart, and McLeod[a] found that the difference in the amount of nitrogen between virgin land and cropped land was not enough to account for the crops removed, and they suggest that this fact is due to the removal of nitrogen by bacteria. Their work was carried on in humid regions, however, where leaching would affect the distribution of nitrogen in the soil.

In an area such as the prairie region represented, where the amount of rainfall is rather limited, there would be an accumulation in the fallow plat of both water-soluble and albuminoid nitrogen. The crop would have the advantage of the nutritive condition of the soil solution represented on July 31 in figure 1, as compared with the less favorable conditions obtaining on April 27 in figure 2.

It should be kept in mind that the plats on which the determinations were made were "dry farmed," and it is not intended strictly to apply to irrigated lands the conclusions derived from this work. Irrigation would in all probability cause disturbances in the bacterial processes in the soil, and so, to some extent at least, mask the seasonal activities of the bacterial flora by translocation of the nitrates and by intermittent wetting and drying. It is likely, however, that by properly controlling the work the same general phenomena would be observed.

RELATION OF NITRIFICATION TO SUMMER FALLOW.

As will be noticed from figure 3, the summer-fallow plat contained on July 31 about 35 parts per million more of water-soluble nitrates than did the wheat plat, which would present a more favorable nutritive condition than found in the cropped plat. In view of the fact, however, that the fundamental phenomena underlying nitrification are the same in both the cropped plats and the fallow plat, it would seem that summer fallow would be of doubtful economic value so far as the use of nitrates is concerned. The various curves distinctly show that nitrification is affected in degree but not in kind by the presence of a growing crop, and it is certainly likely, with this point in view, that nitrates were formed to as large an extent in the wheat plat as in the summer-fallow plat; interest on the investment would be lost from the fallow land while lying idle, when by suitable treatment of the soil use could as well be made of the products of the nitrifying organisms each year as to allow the land to lie idle. The bacterial groups active in producing soluble nitrates and albuminoid nitrogen, feeding largely on the organic matter in the soil, would of course reduce their food supply more rapidly in a system of fallowing than in a system of crop rotation, where organic matter is continually being added to the soil. Another serious objection to summer fal-

[a] Whitson, A. R., Stoddart, W. C., and McLeod, A. F. Twenty-Third Annual Report, Agricultural Experiment Station of the University of Wisconsin, 1906, pp. 160–170.

lowing, aside from the one just mentioned, is the fact that favorable conditions for chemical oxidation of the organic matter obtain because of the more ready access of heat to the soil due to its exposed condition. So in an area such as is represented by this station where even so far as moisture is concerned fallowing is questionable as a system, the nitrifying flora would be served better by eliminating fallowing.

SUMMARY.

In the early part of spring the surface 6 inches of soil contained more water-soluble nitrates than the lower 6-inch layers, and the amount reached its maximum in the first layer in the first and second weeks in May.

From that time the amounts of water-soluble nitrates decreased in the surface layer, and at the same time the nitrates in the 12-inch layer increased rapidly for one to two weeks, when a decrease was in turn shown in that layer; similarly with the 18-inch and 24-inch layers.

Thus the successive 6-inch layers from the surface 6-inch layer downward, at periods of about two weeks apart, each contained more water-soluble nitrates than any other layer at the same date, and each layer after accumulating a maximum amount showed a decided decrease, which it never again made up.

An exception was the 24-inch layer, which, while it showed the same phenomenon as distinctly, did not at any time accumulate more nitrates than any other layer, but underwent the same general changes as the upper layers.

The respective soil layers in the fallow plat reached their individual maximum accumulation of nitrates about a week earlier than the corresponding layers in the wheat plat. From June 12 to June 19 all soil layers in both plats suffered a general decrease in amounts of water-soluble nitrates. This occurrence took place in the spring-wheat plat in the same order and in about the same magnitude as in the fallow plat.

No evidence could be brought out that the wheat-plant roots drew more heavily on the water-soluble nitrates in one 6-inch soil layer than in any other at any time. The general decrease of nitrates in all of the soil layers in the fallow plat masked any such reduction by the wheat if any occurred.

The corn plants at the end of their most active season of growth had reduced the amounts of water-soluble nitrates in the soil to the same degree of exhaustion as had the wheat plants in the corresponding period of their development. The roots of the corn plants probably used the nitrates in the surface soil layer first, then drew most heavily upon the 12-inch layer, and finally upon the 18 and 24 inch layers. This progressive downward feeding of the corn roots occupied

the time from June 19 to July 17; at the latter date the nitrates had probably been reduced by the corn roots to the lowest limit possible.

The wheat and corn plants reduced the nitrates to a constant amount—about 15 parts per million in the dry soil. The wheat removed the moisture also to a fairly constant degree, namely, about 15 per cent.

Denitrification, as measured by the nitrites found, could not account for the changes occurring in the nitrate content in the soil layers.

No correlation could be established between the amounts of nitrates and the air temperature or between the nitrates and the soil moisture.

Translocation of the nitrates by rain could not account for the seasonal changes in the amounts of nitrates in the different soil layers.

The general increase and decrease in water-soluble nitrates followed the same course in the fallow plat and in the cropped plats, the only general difference being that there were more nitrates in the fallow plat after May 16 than in the wheat plat.

It is suggested:

(1) That the marked increase in the amounts of water-soluble nitrates in the individual soil layers, followed by marked decrease in the same, and not at any time again reaching the same quantity, is due to a seasonal physiological activity of the bacterial flora, depending upon the climatic and nutritive factors in the soil, or else the seasonal changes are due to a rythmic periodicity of activity in the nitrifying organisms during the season, the nature of which could not be made clear by the data obtained.

(2) That the general decrease in amounts of water-soluble nitrates from June 12 to June 19 may be due to the formation of albuminoid nitrogen by other groups of bacteria which may have become most active at this time; that the excessive accumulation of nitrates or the accumulation of other by-products by the nitrifying organisms may have inhibited further activity on their part.

(3) That, while the summer-fallow plat contained at the end of the season more water-soluble nitrates than did the corn and wheat plats, the same general phenomena of nitrification are found to take place in both fallow and cropped plats; hence the extended practice of summer-fallowing would seem to be of doubtful value so far as the accumulation of nitrates in the soils represented by this station is concerned.

NOTE.—Since this bulletin was put into type, a review of Kansas Station Bulletin 161, appearing in the Experiment Station Record, vol. 22, no. 1, p. 21, gives as one of the conclusions arrived at by the authors, that "bacterial life and activity seem to rise and fall with more or less regularity. These periods of maximum and minimum activity are to a certain extent independent of moisture and temperature, and are possibly due to the presence of bacterial by-products." This conclusion corresponds closely with the work herein described and shows that other bacterial groups besides the nitrifying flora have the periodicity mentioned in this bulletin.

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U. S. DEPARTMENT OF AGRICULTURE.
BUREAU OF PLANT INDUSTRY—BULLETIN NO. 174.
B. T. GALLOWAY, *Chief of Bureau.*

THE CONTROL OF PEACH BROWN-ROT AND SCAB.

BY

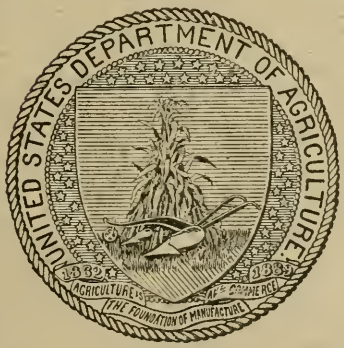
W. M. SCOTT, PATHOLOGIST,

AND

T. WILLARD AYRES, SCIENTIFIC ASSISTANT,

FRUIT-DISEASE INVESTIGATIONS.

ISSUED MARCH 5, 1910.



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FRUIT-DISEASE INVESTIGATIONS.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., December 15, 1909.

Sir: I have the honor to transmit herewith a manuscript entitled "The Control of Peach Brown-Rot and Scab," by Mr. W. M. Scott, Pathologist in Charge of Orchard Spraying Experiments and Demonstrations, and Mr. T. W. Ayres, Scientific Assistant, Fruit-Disease Investigations, and recommend it for publication as a bulletin of the special series of this Bureau.

The summer spraying of peaches has for years been a puzzling problem on account of the injury to the foliage resulting from the use of various mixtures. After repeated trials a fungicide was found in 1907 in the form of self-boiled lime-sulphur which prevents diseases without injury to the foliage.

The experiments with this material were repeated on a larger scale in 1908. During the past season (1909) the treatment was demonstrated on a block of 5,000 trees and further details were worked out by experiment. The present paper describes these demonstrations and experiments and gives a summary of the three seasons' work, with recommendations for the treatment of orchards.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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THE CONTROL OF PEACH BROWN-ROT AND SCAB.

INTRODUCTION.

The susceptibility of peach foliage to injury from applications of the usual copper fungicides has largely prohibited summer spraying for the control of peach diseases. The diseases preventable by dormant spraying, such as leaf-curl and the California peach blight, have been easily overcome, but those requiring summer treatment have, as a rule, been allowed to go unchecked for the want of a suitable fungicide. The peach has therefore largely had to fight its own battles against some of its worst enemies, with the result that the growers of this fruit have annually sustained heavy losses.

During the past few years the Bureau of Plant Industry has endeavored to develop a fungicide that could be safely used on the peach during the growing season to prevent some of the diseases of the fruit and foliage. Various copper compounds in both liquid and dust form were tested without satisfactory results. Experiments with sulphur in various forms showed that the soluble sulphids were even more caustic than Bordeaux mixture, and no encouragement was obtained from the work until the so-called self-boiled lime-sulphur mixture was tested.

In the experiments of 1907, the results of which were published in Circular No. 1 of the Bureau of Plant Industry,[a] it was found that self-boiled lime-sulphur could be used as a spray on the peach without injury to fruit or foliage. Brown-rot infections were held down to 10 per cent of the crop, while 73 per cent of the fruit on the unsprayed trees rotted. The same treatment prevented the peach scab, or black-spot, and some leaf diseases.

Experiments conducted by the writers during 1908 at Marshallville, Ga., Bentonville, Ark., and Neoga, Ill., verified the previous year's results and gave sufficient data to warrant the recommendation of this mixture for general use in peach-growing districts where brown-rot and scab are prevalent. The results of the 1908 experiments, with suggestions for the treatment of brown-rot and scab, were published in Circular No. 27 of the Bureau of Plant Industry.

[a] These results were first reported by the writer at the Jamestown meeting of the American Pomological Society, September 25, 1907, and were published in the proceedings of that meeting. They were also presented before the Missouri State Horticultural Society, December 5, 1907, by Mr. F. W. Faurot, who assisted in the work.

During the past season (1909) the work on this important problem was carried out on a large scale somewhat in the nature of a demonstration. The results of this work, together with directions for preparing and applying the mixture for the treatment of brown-rot and scab, are presented in the following pages.

The peach grower now has at his command an effective weapon with which to combat two of his worst fungous enemies—brown-rot and scab. In view of the excellent results obtained from the experiments of the past three years, the writers are of the opinion that self-boiled lime-sulphur will soon become almost, if not quite, as indispensable to the peach grower as Bordeaux mixture has been to the apple grower.

PEACH BROWN-ROT.

HISTORY OF THE DISEASE.

The fungus causing brown-rot was first described by Persoon[a] in 1796 as *Torula fructigena*, and he later transferred it to the genus Monilia. In 1893 Schröter[b] placed the fungus in the ascomycetous genus Sclerotinia, although its perfect stage was not known until discovered by Norton[c] in 1902. The fungus is reported by Saccardo[d] as occurring in Great Britain, Germany, France, Italy, Belgium, and Austria, as well as in the United States. Perhaps the first to recognize it as of economic importance were Von Thümen[e] and Hallier[f] and it has been discussed by Frank,[g] Prilleux,[h] Wehmer,[i] Sorauer,[j] Woronin,[k] Aderhold,[l] and other European writers who have contributed largely to our knowledge of the life history of this fungus.

In the United States this disease has been known for many years and has had more or less attention from nearly all the pathologists of this country. In 1881 Peck[m] gave what appears to be the first economic account of the disease, and since that time it has been the subject of study by a large number of investigators, notably Arthur,[n] Gallo-

[a] Observationes Mycologicæ, vol. 1, p. 26.

[b] Kryptogamen Flora von Schlesien, vol. 3, Pilze, p. 67.

[c] Transactions, Academy of Science, St. Louis, vol. 12, no. 8, 1902, pp. 91–97.

[d] Sylloge Fungorum, vol. 4, 1886, p. 34.

[e] Oesterreiches Landwirtschaftliches Wochenblatt, no. 41, 1875, p. 484; see also Fungi Pomicoli, 1879, pp. 22–24.

[f] Wiener Obst- und Garten- Zeitung, 1876, p. 117.

[g] Krankheiten der Pflanzen, 2d ed., vol. 2, 1896, p. 360.

[h] Maladies des Plantes Agricoles, vol. 2, 1897, pp. 449–453.

[i] Berichte der Deutschen Botanischen Gesellschaft, vol. 16, 1898, pp. 298–300.

[j] Berichte der Deutschen Botanischen Gesellschaft, vol. 17, 1899, pp. 186–189.

[k] Mémoires de l'Académie Impériale des Sciences de St.-Pétersbourg, ser. 8, vol. 10, no. 5, 1900, pp. 18–29.

[l] Berichte der Deutschen Botanischen Gesellschaft, vol. 22, 1904, pp. 262–266.

[m] Thirty-fourth Report, New York State Museum, Natural History, 1881, pp. 34–36.

[n] Fourth Report, New York Agricultural Experiment Station, 1886, pp. 281–285.

way,[a] Erwin F. Smith,[b] Humphries[c] and Quaintance.[d] Various other articles dealing principally with the treatment of this disease have appeared in bulletins of the state experiment stations and of the United States Department of Agriculture, and in agricultural journals.

Hygienic measures, such as the removal of rotting and mummied fruits and the pruning out of diseased twigs, have been strongly recommended for the control of brown-rot, and most writers have advised spraying with dilute Bordeaux mixture; but only in rare instances have these remedial measures been successful. In spite of the fact that in a wet season when treatment is most needed Bordeaux mixture and other copper compounds injure peach leaves and defoliate the trees, nearly all the recent publications on the subject have recommended spraying with these fungicides, the authors believing that the benefit would more than counterbalance the injury.

ECONOMIC IMPORTANCE OF THE DISEASE.

With the possible exception of peach yellows, which kills the tree outright, brown-rot has for years been recognized as the most destructive disease of stone fruits, such as peaches, plums, and cherries. It also affects the apple, pear, and quince, but only in rare cases does it become a serious pest on these pomaceous fruits. The disease is well distributed over the United States, and in most of our humid sections it has practically prohibited the commercial production of the European plum and often destroys a large portion of the crops of peaches, Japanese plums, and cherries. The average annual loss to the peach growers of this country easily reaches $5,000,000. Quaintance[e] estimated the loss in Georgia for the year 1900 at from $500,000 to $700,000. The number of bearing trees in that State has more than doubled since that time and the brown-rot has not abated in the least, so that a conservative estimate of the loss at the present time with a fair crop of fruit set and under average brown-rot conditions would be $1,000,000; in fact, the writers are convinced that the loss during the past season, with only a third of a crop, almost reached that figure. Similar losses occur in other Southern States, and the more northerly peach districts are by no means exempt. Dr. Erwin F. Smith[f] placed the loss on the Chesapeake and Delaware peninsula

[a] Report, Commissioner of Agriculture, 1888, pp. 349–352.

[b] Journal of Mycology, vol. 5, no. 3, 1889, pp. 123–134; also vol. 7, no. 1, 1891, pp. 36–39.

[c] Eighth Report, Massachusetts Agricultural Experiment Station, 1891, p. 213; also Botanical Gazette, vol. 18, 1893, pp. 85–93.

[d] Bulletin 50, Georgia Agricultural Experiment Station, 1900, pp. 237–269.

[e] Bulletin 50, Georgia Agricultural Experiment Station, 1900, p. 245.

[f] Journal of Mycology, vol. 5, no. 3, 1889, pp. 123–134.

in 1888 at 800,000 baskets (of five-eighths of a bushel), worth $400,000, which he considered a very conservative estimate. The same writer states that the following spring (April and May, 1889) this section experienced an outbreak of the brown-rot on the blossoms and young fruits which destroyed the greater part of the peach crop in four counties, resulting in a loss of at least 500,000 baskets.

Dr. C. P. Clinton[a] reports that in Connecticut "brown-rot of peaches and plums is always present at harvest time, some seasons becoming so prevalent that it sweeps away a large part of the profits in a few days." The same may be said of the prevalence of this disease in Michigan, Missouri, Arkansas, and in other peach-growing States.

In California, Prof. Ralph E. Smith[b] reported that during 1905 and 1906 the brown-rot was "quite abundant and destructive on apricots, some plums, and early peaches, especially near the coast." It has also been reported from Oregon by Prof. A. B. Cordley[c] as causing excessive rotting of plums in 1897 and 1898 and to a less extent affecting peaches.

The effect of this disease does not cease with the fruit growers, but is felt by the transportation companies, the commission men, and the consumers. Although the fruit may be carefully sorted at the packing house and only sound specimens packed, the disease often continues to develop en route to market, especially if the refrigeration is not good. In an orchard where the disease is prevalent, the healthy fruits easily become contaminated through handling by the pickers and packers, and enough moisture develops in the car through the "sweating" of the fruit to germinate the spores. It thus not infrequently happens that peaches from the Southern States reach the market "specked" and must be sold at half the value of sound fruit. The commission man is often blamed by the shipper for the low returns received, when the trouble is really due to brown-rot. On several different occasions the senior writer has been in the New York market when from thirty to over a hundred cars of southern peaches were sold from 2 to 6 o'clock in the morning and 25 to 50 per cent of the fruit from a large number of these cars was found to be affected with brown-rot. In recent years this condition has so often prevailed that the board of health of New York City deemed it necessary to designate a special health officer whose duty is to inspect the fruit as it is unloaded from the cars and prohibit the sale of such as is badly affected with brown-rot. Fruit arriving in poor condition demoralizes the market to such an extent that where 50 cars of sound

[a] Report, Connecticut Agricultural Experiment Station, 1903, p. 286.

[b] Bulletin 184, California Agricultural Experiment Station, p. 248.

[c] Bulletin 57, Oregon Agricultural Experiment Station, pp. 3–5.

peaches may be readily sold at good prices 15 or 20 cars of fruit specked with brown-rot are sufficient to create a "glut" and often bring scarcely enough to pay expenses.

NATURE OF THE DISEASE AND THE FUNGUS CAUSING IT.

Brown-rot is a fungous disease which affects the fruit of the peach, causing it to decay on the trees or en route to market. As already stated, it is caused by a fungus whose botanical name is *Sclerotinia fructigena* (P.) Schröt. Many fruit growers call it Monilia, the name given to the summer stage of the fungus before the perfect form was known. The fungus also attacks the blossoms and twigs, thus often destroying a portion of the fruit crops at blooming time. The diseased blossoms turn brown and become dried, adhering to the twigs for some weeks. The fungus may extend from the dead blossom into the bark, forming a small brown canker which frequently girdles the twig. In low, damp situations, especially in a wet spring, many blossoms and fruit-bearing twigs may thus be destroyed. Some of the green fruits may become affected at any time during the season, and even young peaches half an inch or less in diameter may rot, but as a rule no serious outbreak occurs until the fruit is nearing maturity. It is at harvest time ordinarily that the greatest destruction is wrought.

On the fruit, brown-rot may at first be observed as a small circular brown spot, which under favorable conditions rapidly enlarges, until within two or three days the entire peach goes down in decay. While the spot is yet small, whitish tufts of spore-bearing threads begin to appear. As the spot enlarges, these tufts, arranged more or less in concentric rings, become so numerous as nearly to cover the surface, giving the diseased area a grayish, moldy appearance. (See Pl. I.) Most of the rotten fruit drops to the ground, but a considerable portion of it may shrivel up on the tree and remain attached until the following season. As in the case of diseased blossoms, the fungus may extend from the rotting peaches into the twigs, killing them and thus reducing the prospects of a crop the following year. In a wet season some varieties suffer so badly from twig infections that the trees have the appearance of a pear tree attacked by blight.

The fungus passes the winter in the mummified peaches hanging on the trees, as well as in those that have fallen to the ground. During the spring and summer, especially in wet weather, the fungus in these mummies produces large crops of summer spores for the infection of the new fruit crop. In the mummies on the ground the fungus forms a black leathery sclerotium, which is the foundation of another kind of spore production. In the spring, during the blooming period, small, brown cup-shaped bodies (apothecia), resembling toad-

stools, about one-half inch in diameter, are produced from mummies which have remained on the ground through two winters partially or entirely covered with soil. (See fig. 1.) One mummy may produce ten to fifteen of these bodies, each of which produces myriads of ascospores. When disturbed by a puff of wind a little cloud of spores may be seen to rise into the air from one of the cups. These ascospores, as well as the conidia, serve to infect the blossoms. A crop of summer spores is in turn produced on the diseased blossoms and some of the young, green fruits become infected by these, so that there is usually a great abundance of material ready for the infection of the mature crop of fruit, even if the old mummies have been removed from the trees.

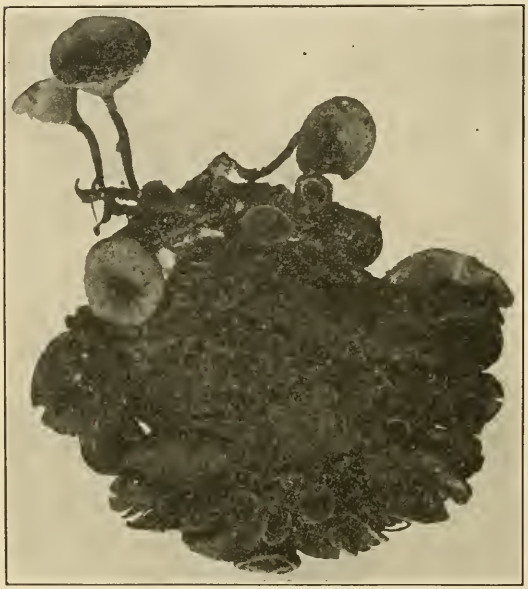

FIG. 1.—An old brown-rot mummy with the cup-shaped bodies (apothecia) of the fungus, in which myriads of ascospores are produced.

It has for years been recommended that the rotten fruit be picked from the trees and from the ground and destroyed in order to remove the source of infection for the following year's crop. This is a good practice, but it is usually disappointing, because the fungus is so prolific in spore production that the few mummies that inevitably escape the pickers are sufficient to furnish the initial infection material for the entire crop of the following year. Protection of the fruit by spraying appears to be the only satisfactory means of combating this fungus, although the destruction of diseased fruits doubtless aids in checking it and should not be discouraged.

INFLUENCE OF THE WEATHER.

Most parasitic fungi are influenced by weather conditions. This is especially true of the brown-rot fungus. Moisture not only favors the growth of the fungus and the production and germination of the spores, but it also renders the fruit tender and watery and therefore more susceptible to rot. In a dry season, or one with only occasional rains of short duration, a peach crop may be expected to reach maturity practically free from rot, particularly if the weather is cool; but when

a series of cloudy days with frequent showers occurs about picking time, half or even all of the crop may be destroyed by brown-rot. Prolonged cloudy, drizzly weather, even though the precipitation may not be great, is far more dangerous than a heavy rain followed by clearing. Hot weather also favors the rapid growth of the fungus and increases the danger of its destroying the crop.

INFLUENCE OF INSECTS.

The spores are undoubtedly distributed broadcast by the wind, so that they are in most cases ever present on the fruit ready to produce an outbreak of the disease when the conditions are favorable. Although the fungus appears to be able to enter the peach through the unbroken skin, entrance is more readily accomplished through abrasions such as are made by insects and through cracks due to the scab fungus. Sucking insects of the squash-bug family (Coreidæ) have been observed to puncture healthy and diseased fruits indiscriminately,[a] thus not only distributing the spores but probably inserting them into the peach. But the curculio is by far the worst offender. It breaks the skin of the peach and leaves a wound through which the fungus readily gains entrance. Although the wound may apparently heal before an outbreak of rot occurs, an exudation of gum often keeps it open sufficiently to admit the fungus. The work of this insect greatly reduces the efficiency of fungicides applied for the control of brown-rot. It punctures the fruit through the coating of spray, possibly inserting brown-rot spores and certainly leaving an opening for the fungus. In experiments conducted by the Bureau of Plant Industry in cooperation with the Bureau of Entomology it was found that 93 per cent of the brown-rot infections on sprayed fruit had taken place through curculio punctures. It is evident, therefore, that in order to secure the best results from spraying for brown-rot, the curculio must also be controlled.

PEACH SCAB.

CHARACTER OF THE DISEASE.

Peach scab is a disease caused by the fungus *Cladosporium carpophilum* Thüm. It is also known as black-spot, and peach growers often call it "freckles," which is an appropriate name, owing to the freckled appearance the disease gives to the fruit. The spots are dark brown or blackish, circular in outline, and about one-eighth of an inch or less in diameter. They are often so numerous that one side of the peach has a "smutty" or blackish appearance, cracks open, and shrivels. (See Pl. III, figs. 1 and 2.)

[a] Scott and Fiske. Bulletin 31, Division of Entomology, U. S. Dept. of Agriculture, p. 29.

The disease mars the appearance of affected fruit, reducing its market value and often rendering much of it unsalable. The large cracks which occur in severe cases open the way for brown-rot, and in addition the skin under the individual spots is usually broken, exposing the peach to attacks of the fungus. Preventing the scab is therefore an important step in the control of brown-rot.

The fungus forms brown spots on the twigs where it passes the winter. So far as is known at present, these twig spots are the chief source of infection of the fruit. Fruit infection begins to take place about three to four weeks after the petals fall, although the spots do not show until about three weeks later. Infections continue to take place until about a month before the fruit matures.

ECONOMIC IMPORTANCE OF THE DISEASE.

Peach scab has been known in this country for many years, and it occurs to an injurious extent wherever peaches are grown east of the Rocky Mountains. The damage done by this disease is apparently not fully realized by peach growers. Scab spots are so common on the peach that most of the eastern growers have come to take the disease as a matter of course and scarcely realize that their fruit is bringing 25 per cent less in the market than the same fruit free from scab would bring. Moreover, the fungus has a tendency to dwarf the fruit and prevent it from attaining full size, so that a considerable loss in yield is thus sustained.

On the other hand, some growers recognize it as their worst enemy, and in many localities it practically prohibits the growing of certain varieties. Some of the large orchards in the mountains of West Virginia and western Maryland have sustained heavy losses from this disease, and the growers have been obliged to confine their plantings of such late varieties as Bilyeu and Salway to the high ridges in order to avoid scab. The Bilyeu is very valuable commercially, but the scab has restricted its successful production to the higher points.

It has been known for some years that peach scab could be controlled by applications of Bordeaux mixture, but its use for this purpose has been discouraged by its injurious effects upon peach foliage. The disease has therefore been practically without a satisfactory remedy.

SPRAYING FOR THE CONTROL OF PEACH BROWN-ROT AND SCAB IN 1909.

As stated in the introduction of this paper, peach brown-rot and scab were effectively controlled by spraying with a self-boiled lime-sulphur mixture in experiments conducted during 1907 and 1908. The work of 1907 was confined to small plats in one orchard, while that of 1908 involved several orchards in different localities, aggregating about 2,000 trees.

During 1909, in order to place the treatment on a better commercial basis, large blocks of several different varieties, comprising over 5,000 trees, were sprayed. This was more in the nature of a demonstration than an experiment, although some features of the work were purely experimental, as will be seen in the following pages. In addition to this block, about 7,000 trees in the same orchard were sprayed by the owner under the supervision of the writers.

The work was conducted in the orchard of the Hale Georgia Orchard Company, at Fort Valley, Ga., and the writers are indebted to Mr. J. H. Hale, president of the company, and Mr. J. H. Baird, its superintendent, for their hearty cooperation and valuable assistance. This orchard was in good condition, having been well cultivated, fertilized, and pruned, but in recent years the brown-rot had become exceedingly bad. The crop of 1908 was largely lost on account of brown-rot, scab, and curculio, and the conditions were particularly favorable for a severe test of the self-boiled lime-sulphur treatment. Unfortunately, however, in this orchard, as in most of the Georgia orchards the past season, the crop was very light for all varieties and the yield per tree quite low, but the value of spraying was, nevertheless, strikingly demonstrated.

The spraying was done with a power outfit consisting of a 2-horsepower gasoline engine, a triplex pump, a 200-gallon tank, a propeller agitator, two 25-foot leads of discharge hose, Vermorel nozzles, etc. The mixture was prepared according to the following formula and directions.

PREPARATION OF SELF-BOILED LIME-SULPHUR MIXTURE.

The mixture used in our experiments during the past season was composed of 8 pounds of fresh stone lime and 8 pounds of sulphur (either flowers or flour may be used) to 50 gallons of water. This appears to be about the correct strength, although in mild cases of scab and brown-rot a weaker mixture, containing 6 pounds of each ingredient to 50 gallons of water, may be used with satisfactory results. The mixture can best be prepared in rather large quantities—say, enough for 200 gallons at a time, making the formula 32 pounds of lime and 32 pounds of sulphur, to be cooked with a small quantity of water (8 or 10 gallons) and then diluted to 200 gallons.

The lime should be placed in a barrel and enough water poured on to almost cover it. As soon as the lime begins to slake the sulphur should be added after first running it through a sieve to break up the lumps. The mixture should be constantly stirred and more water added as needed to form a thick paste at first and then gradually a thin paste. The lime will supply enough heat to boil the mixture several minutes. As soon as it is well slaked, water should be added

to cool the mixture and prevent further cooking. It is then ready to be strained into the spray tank, diluted, and applied.

The stage at which cold water should be poured on to stop the cooking varies with different limes. Some limes are so sluggish in slaking that it is difficult to obtain enough heat from them to cook the mixture at all, while other limes become intensely hot on slaking and care must be taken not to allow the boiling to proceed too far. If the mixture is allowed to remain hot fifteen or twenty minutes after the slaking is completed, the sulphur gradually goes into solution, combining with the lime to form sulphids, which are injurious to peach foliage. It is therefore very important, especially with hot lime, to cool the mixture quickly by adding a few buckets of water as soon as the lumps of lime have slaked down. The intense heat, violent boiling, and constant stirring result in a uniform mixture of finely divided sulphur and lime, with only a very small percentage of the sulphur in solution. The mixture should be strained to take out the coarse particles of lime, but the sulphur should be carefully worked through the strainer.

SELF-BOILED LIME-SULPHUR TREATMENT AND RESULTS.

Several different varieties of peaches were sprayed with good results. The details of the work were about the same in each case, the following notes on the Waddell variety serving as an example of the treatment given and the results obtained:

Plat 1, consisting of 568 Waddell trees, was sprayed with self-boiled lime-sulphur (32-32-200) on April 30, about one month after the petals dropped, and again on May 20, three to four weeks before the fruit ripened. At picking time the entire crop, including dropped fruit from five average trees in this plat, was sorted and counted, with the result that 17 per cent was found to be affected with brown-rot. An examination of the rotting fruits showed that 93 per cent of the infections had taken place through curculio punctures and that aside from such infections only 1 per cent of the crop was affected with brown-rot.

From a commercial standpoint, the scab or black-spot was completely controlled, although 16 per cent of the fruit showed some slight infections. None of the fruit was sufficiently spotted to injure its market value.

Check A consisted of 1,357 unsprayed Waddell trees in a block adjacent to plat 1. Of the fruit from five average trees in this block 49½ per cent was affected with brown-rot and 91½ per cent with scab. About one-third of the scabby fruit, or 28½ per cent of the total crop, was so badly spotted and cracked that it had to be discarded as unmerchantable. In this case 81 per cent of the brown-rot infec-

tions had apparently taken place through curculio punctures. In the actual counts of diseased specimens from plat 1, as compared with the unsprayed plat, there was a difference in favor of spraying of 32½ per cent in the case of brown-rot and 75½ per cent in the case of scab. These figures do not tell the whole story. The sprayed fruit was larger, more highly colored, and presented a much better appearance in the package; it carried to the market in better condition and commanded a higher price than the unsprayed fruit.

Plat 2 was a block of 1,275 Waddell trees sprayed only once to determine the value of a single application. The spraying was done on April 30, a month after the petals dropped. The intention was to make this application at a time when it would be expected to accomplish the best results against scab. The Waddell is one of the worst of the early varieties to scab, and to control this disease is an important step in the control of brown-rot.

The sorting record of the fruit from five trees in this block showed that 32 per cent was affected with scab and 12½ per cent with brown-rot. The percentage of scabby fruit ran rather high, but the spots were mostly small and scattered, so that only 2 per cent of the crop was badly affected. If the disease is kept down to two or three spots on each fruit the damage is very slight even though a large percentage of the crop may be so affected. The unsprayed trees of this variety, as pointed out above, had 91½ per cent of the fruit affected with scab, while 28½ per cent of the crop was so badly spotted with the disease as to be unmerchantable. One spraying, therefore, made a difference of 59½ per cent in the amount of fruit affected with scab and resulted in an actual saving of 26½ per cent of the crop from destruction by scab.

COMMERCIAL RESULTS.

In order to determine the commercial results a record was made of the marketable fruit from each plat. The fruit was brought into the packing house, sorted, and packed in the usual way. The number of trees in each plat varied, ranging from 568 to 1,357, and for convenience of comparison the average yield for 500 trees in each plat is given as follows: Plat 1, 160 crates; plat 2, 170 crates; and the check or unsprayed plat, 80 crates.

This record of yield corresponds closely to the results expressed in percentages of diseased fruit as determined by sorting the crop from five trees in each plat. In such large plats considerable variation in the trees and environment would naturally be expected and there was perhaps a sufficient difference between plat 1 and plat 2 to account for the fact that the latter, which was sprayed only once, had less brown-rot and more good fruit than the former, which was

sprayed twice. The check plat, which lies between plats 1 and 2, certainly represents something near the average conditions for the whole block involved and the difference in yield between the sprayed and the unsprayed trees was, for the most part, undoubtedly due to the effect of the spraying. The application of self-boiled lime-sulphur, therefore, apparently increased the yield by 100 per cent.

SELF-BOILED LIME-SULPHUR AND ARSENATE OF LEAD IN COMBINATION.

It has been known for many years that the curculio is an important factor in the distribution of brown-rot and that to prevent the former would be an important step toward controlling the latter. In our first lime-sulphur experiments during 1907 the interference of this insect with the efficacy of spraying for the control of brown-rot was again clearly brought out. In discussing the results of that year's work the senior writer stated that "the plum curculio punctures the skin of a certain percentage of the fruit and admits the fungus in spite of all spraying that can be done."[a] Although in most of our experiments the brown-rot has been held down by spraying to about 10 to 15 per cent where the unsprayed fruit ran 50 to 70 per cent of brown-rot, it has nevertheless been apparent in all the work that spraying for brown-rot would not be entirely satisfactory so long as the curculio was not also controlled.

Entomologists have known for many years that the curculio could be controlled by the application of arsenical poisons, but owing to the danger of injury to both fruit and foliage they have very properly been cautious about recommending their use on peach trees. Mr. A. L. Quaintance, of the Bureau of Entomology, during the past five or six years, has experimented extensively on the use of arsenate of lead for spraying peach trees, with the result that a high percentage of curculio injury was always prevented by two or three sprayings beginning soon after the petals dropped. In 1905 he recommended with due caution the spraying of peach trees with arsenate of lead for the control of this insect.[b] Mr. E. P. Taylor,[c] of the Missouri Fruit Experiment Station, recently reported that during 1908 he had obtained a high percentage of fruit free from curculio by the use of arsenate of lead, with very little injury to the foliage. He also noted a very marked reduction of brown-rot on the sprayed trees.

In order to test the practicability of combining arsenate of lead with self-boiled lime-sulphur as a combination treatment for scab, brown-rot, and curculio, one of our principal experiment blocks at Fort Valley, Ga., was devoted to this purpose. This work was car-

[a] Circular 1, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1908, p. 16.

[b] Yearbook, U. S. Dept. of Agriculture, for 1905, p. 329.

[c] Journal of Economic Entomology, vol. 2, 1909, p. 156.

ried on in cooperation with Mr. Quaintance. A block of 2,324 Elberta peach trees, 7 years old, was selected for this test and nearly half of it sprayed, the remainder being left unsprayed as a check. The results of the treatment were exceedingly satisfactory, as will be seen in the following notes.

The treated portion, designated as plat 6, consisted of 1,100 trees, not quite half of the block. These trees were sprayed as follows:

(1) With arsenate of lead, 2 pounds to 50 gallons of water, on March 31, as the dried calyces (or shucks) were shedding. This application was intended for the curculio only, and as the date was too early for serious brown-rot and scab infection the lime-sulphur was omitted.

(2) With 8–8–50 self-boiled lime-sulphur and 2 pounds of arsenate of lead combined, on April 22, three weeks after the first treatment.

(3) With self-boiled lime-sulphur alone, on May 21.

(4) With self-boiled lime-sulphur alone, on June 9, about one month before the fruit ripened.

The curculio treatment necessitated an extra application before the time to begin using the fungicide, thus increasing the cost. However, the cost of materials, labor, and teams for these four sprayings was only $62.38, or 5⅜ cents for each tree. Moreover, the writers are of the opinion that only three applications, as outlined below, will be required to secure satisfactory results, thus reducing the cost. The trees were watched closely throughout the season and no injury to fruit or foliage was observed.

When the mature fruit, including windfalls, from five average trees in this plat was sorted and counted, it was found that only 4½ per cent was affected with brown-rot, about half of which apparently resulted from curculio punctures. Only 6½ per cent of the fruit showed scab infections, and these were mostly small, obscure specks. The curculio infestation was 27½ per cent of the crop.

The check was composed of 1,224 unsprayed Elberta trees adjacent to the sprayed block. The trees in the two blocks were of the same age and were growing under the same conditions of soil, cultivation, etc., the only difference being that one block was sprayed and the other was not. The fruit from five of the unsprayed trees when sorted proved to be 63 per cent rotten, 99 per cent scabby, and 97½ per cent wormy from curculio. In other words, the crop was practically a total loss. A comparison of these figures with those of plat 6 (the sprayed part) shows that spraying saved 58½ per cent of the crop from brown-rot, 92½ per cent from scab, and 70 per cent from curculio.

COMMERCIAL RESULTS.

A record kept in the packing house showed that the sprayed block of 1,100 trees yielded 327¼ crates of first-class fruit, while the unsprayed block of 1,224 trees yielded only 33¾ crates, all of which were poor in quality. At the beginning of the season the set of fruit

appeared to be about equal in the two blocks, but was very light in both. So far as could be determined, the difference in yield was due entirely to spraying. It appears, therefore, that in the combined self-boiled lime-sulphur and arsenate of lead spray we have an effective remedy for the peach scab, brown-rot, and curculio, the yield from the sprayed trees in this instance being ten times that from the unsprayed trees.

MARKETING TEST.

In order to determine the carrying quality and market value of the sprayed as compared with the unsprayed fruit, two cars of peaches from the experiment blocks were shipped to New York, examined on arrival, and sold in the usual way through a commission house. This test was accomplished through the cooperation of Mr. Hale and the Georgia Fruit Growers' Exchange.

The fruit for the first car was picked on Friday, July 9, in a drizzling rain, but was not loaded and billed out until the following day. It was due on the New York market the following Tuesday morning, but was delayed en route and was not sold until Wednesday morning, July 14. This car contained Elberta peaches from the lime-sulphur–arsenate-of-lead block and from the adjacent check block, Belle peaches sprayed three times with lime-sulphur alone, and unsprayed Belles. The market was almost glutted with poor fruit and the prices were at about the lowest point of the season. The fruit was sold at the following prices:

Sprayed Elbertas	$2.00 per crate.
Unsprayed Elbertas	1.50 per crate.
Sprayed Belles	1.25 per crate.
Unsprayed Belles	1.12½ per crate.

The fruit of the second car was picked on Monday, July 12, and was sold on Thursday morning, July 15. This car contained Elbertas sprayed twice and Belles sprayed three times with the self-boiled lime-sulphur; also unsprayed fruit of both varieties. The fruit of this car brought the following prices:

Sprayed Elbertas	$1.45 per crate.
Unsprayed Elbertas	1.25 per crate.
Sprayed Belles	1.50 per crate.
Unsprayed Belles	1.14 per crate.

In the first car the difference in favor of the sprayed fruit was 50 cents a crate for Elbertas and 12½ cents a crate for Belles. In the second car it was 20 cents a crate for Elbertas and 36 cents a crate for Belles. An examination of several crates of Elbertas showed that 34 per cent of the unsprayed fruit was specked with brown-rot, while only 6 per cent of the sprayed fruit was so affected. (See Pl. II.) This difference in market value was due to the fact that the sprayed fruit showed less rot, was more highly colored, and had a better ap-

pearance in all respects than the unsprayed fruit. Another significant fact is that in each case all the sprayed fruit was sold before the buyers began purchasing the unsprayed fruit, showing that they readily recognized the superiority of the former. This marketing test indicates that the enhancement in the market value of sprayed fruit would pay the cost of the work several times over.

COST OF THE TREATMENT.

As previously stated, the spraying was done with a gasoline-power outfit of 200-gallon capacity. Three men operating the machine sprayed 900 to 1,000 trees a day. The mixture was prepared in quantities of 32 pounds of lime and 32 pounds of sulphur in a barrel with a small quantity of water, then strained into the spray tank or a supply tank, and diluted to 200 gallons. When the blocks farthest from the mixing platform were being sprayed, a 200-gallon supply tank was used to haul the mixture to the spraying outfit so as to keep the machine in operation and avoid delay as much as possible. One man was required at the mixing station to prepare the mixture, but his time was not entirely occupied in keeping the spraying outfit supplied. In fact, one man should be able to prepare the mixture rapidly enough for five or six spraying outfits.

The quantity of mixture required for each thousand trees varied with the size of the trees. Medium-sized 7-year-old Elberta trees required about 1,400 gallons per thousand for each application. To make that quantity, 224 pounds of sulphur and the same weight of lime were required. The block sprayed with arsenate of lead required 32 pounds of the poison in the first application (when the foliage was scant) and 56 pounds in the second application for each thousand trees.

The price of materials and labor used in the work at Fort Valley, Ga., was as follows: Sulphur (flour), $2.85 per hundred pounds; lime, $1.10 per barrel; arsenate of lead, 12 cents a pound; gasoline, 13 cents a gallon; team (pair of mules), $2.75 a day; and labor, 75 cents a day.

At the above prices the cost of the self-boiled lime-sulphur treatment was $1\frac{1}{5}$ to $1\frac{3}{5}$ cents per tree for each application, or an average of $4\frac{1}{5}$ cents per tree for three treatments. The combination lime-sulphur–arsenate-of-lead treatment cost $5\frac{3}{5}$ cents per tree for four applications. Where labor is higher and working hours shorter the cost would of course be greater, but in the South, under conditions similar to those existing at Fort Valley, it appears that the work can be done at a cost of $15 per thousand trees for each application, or $45 for three treatments. This cost is insignificant when considered in connection with the fact that an increased yield of 25 to 50 per cent, or in some cases 100 per cent, may be expected from the treatment.

DANGER OF INJURY TO THE FRUIT AND FOLIAGE.

If the self-boiled lime-sulphur is properly prepared and applied, there is very little danger of injuring the fruit or foliage. In all of our work during the past season not the slightest injury developed on any of the several thousand trees sprayed. During the season the writers examined several orchards, ranging from 200 to 500 acres, that had been sprayed by the owners with self-boiled lime-sulphur. No serious injury had resulted from the spraying in any of these orchards. Where injury occurred at all, it was only slight and was confined to a few dozen trees, except in one case where there was a general scorching of the foliage throughout the orchard, due, perhaps, to too much boiling of the mixture; but even in this case the result was only a slight thinning of the foliage, which was scarcely sufficient to damage the trees. In each case the mixture was so exceedingly successful as a fungicide that the owner did not consider the slight injury caused by it as worthy of consideration. However, of the thousands of orchards that will probably be sprayed with this mixture, there will doubtless occur from time to time cases of rather serious injury. Such cases in the opinion of the writers will be exceptional and will not be so common or so serious as is Bordeaux injury of the apple.

It was expected that where arsenate of lead was used in these experiments some injury might occur, but neither fruit nor foliage showed any signs of injury. In the first application of poison made when the dried calyces were shedding, no lime-sulphur was used, but in the second, three weeks later, the lime-sulphur mixture and arsenate of lead were used in combination. It seems barely possible that the lime-sulphur preparation may correct the tendency of the arsenate of lead to injure, although no definite evidence on this point has yet been obtained. In the experiments conducted at Marshallville, Ga., last year, peach foliage and fruit sprayed with the self-boiled wash and arsenate of lead combined were slightly injured,[a] but the notes on this work indicate that the injury was due mostly to the lime-sulphur wash, which was boiled too long in an effort to get a large amount of sulphur in solution. Some arsenate-of-lead injury will doubtless occur from time to time, but where the curculio is so bad, as in southern peach orchards, it would seem advisable for the owners to take some risk in the use of the poison to hold this insect in check.

DANGER OF STAINING THE FRUIT.

There is some danger of staining the fruit with the mixture if it is applied within two or three weeks of the ripening period. Mr. C. A. McCue,[b] of the Delaware experiment station, reported good results

[a] Circular 27, Bureau of Plant Industry, U. S. Dept. of Agriculture, pp. 6–7.

[b] Bulletin 85, Delaware Agricultural Experiment Station.

against brown-rot from the use of self-boiled lime-sulphur during 1908, but complained of marring the appearance of the fruit by heavy deposits of lime. The formula that he used (15 pounds of lime and 10 pounds of sulphur to 50 gallons of water) was stronger than necessary, and the spraying was perhaps continued too near the ripening period. In our 1907 experiments this heavy mixture was used and at picking time the fruit was somewhat stained, but the amount of lime used has since been reduced from 15 to 8 pounds in 50 gallons and the staining now is not a serious matter. The Chicago buyers who purchased the sprayed fruit of the orchard at Neoga, Ill., in which our 1908 experiments were conducted, made no complaint of staining, but on the contrary declined to purchase any of the unsprayed fruit on account of bad scab infections. The sprayed fruit of the Georgia experiments showed evidence of the mixture at picking time, but the whitish specks were largely rubbed off in picking, sorting, and packing. It was more highly colored, slightly larger, and presented a much better appearance than the unsprayed fruit. However, in order to avoid whitewashing the fruit, the last application should be made not later than about four weeks before the ripening period and care should be taken to give the peaches a uniformly light coating of fine spray.

RESULTS OBTAINED BY GROWERS IN COMMERCIAL ORCHARDS.

A considerable number of peach growers have already taken up the self-boiled lime-sulphur treatment for the control of scab and brown-rot, and the writers have been able to obtain reports from some of these. Stranahan Brothers, of Bullochville, Ga., were among the first to give it a trial on a commercial scale. In 1908 they sprayed their orchard of 35,000 trees twice with self-boiled lime-sulphur and arsenate of lead. In a letter dated January 13, 1909, they report that, aside from about 50 trees, the leaves of which were slightly burned, "not a leaf or peach was injured and we had no brown-rot and only one-half of 1 per cent of wormy peaches, including culls and drops. In fact, we had no drops, May, June, or otherwise, and had to thin the fruit three times." They sprayed the orchard again in 1909, using about the same treatment, and the junior writer made observations on the results at two different times during the season. It was found that considerable injury to foliage had occurred at several places in the orchard, due perhaps to too much cooking of certain lots, but in no case did this injury appear to be serious, certainly not sufficient to discourage spraying. Peach scab and brown-rot were almost completely controlled, as was the case the previous year.

Miller Brothers, of Okonoko, W. Va., were as quick to take up the treatment, and their work was directed more especially to the control

of peach scab. They sprayed their orchard of 600 acres in 1908 and again in 1909 and report that they obtained good results both seasons. In previous years the scab had been so bad that a large percentage of the crop was lost each year, and the owners considered the orchard unprofitable until the lime-sulphur treatment made possible the control of this disease without injury to the foliage.

During 1908 the Sleepy Creek Orchard Company, of Sleepy Creek, W. Va., sprayed their orchard of 15,000 peach trees from three to six weeks after the petals fell with 8–8–50 self-boiled lime-sulphur. A portion of the orchard was sprayed again a month later. Fortunately in this orchard trees were left unsprayed as checks and the difference between the sprayed and unsprayed fruit was so striking that the writers deemed it worth while to sort the fruit from several trees and obtain exact percentages of scab infections. From an Elberta tree sprayed twice there were 1,551 peaches, 15 per cent of which was slightly affected with scab and none badly scabbed. Another Elberta tree sprayed only once had 731 peaches, 44 per cent of which showed some scab spots, but only 1.3 per cent was badly scabbed. (See Pl. IV, fig. 1.) An unsprayed tree in the check block had 468 peaches, all of which were affected and 86 per cent badly scabbed. (See Pl. III, fig. 2, and Pl. IV, fig. 2.) These three trees selected for this count work were situated close together in a rather low place where the scab would naturally be bad. It will be observed that one spraying held the disease in check, so that only a little more than 1 per cent of the crop was badly affected, while 86 per cent of the unsprayed fruit came in this class. However, it would not be wise to conclude from this that one application is sufficient. It is shown that 44 per cent of the fruit sprayed once had some scab infections. The second application reduced this to 15 per cent, none of which was bad. In other words, all of the fruit from the trees sprayed twice was suitable for packing, and none of it had enough scab to attract attention; all but 1 per cent of the fruit from the trees sprayed once was suitable for packing, but had enough scab infections to detract somewhat from its appearance, while 86 per cent of the fruit from the unsprayed trees was entirely unsuited for the market and the remainder was sufficiently affected to decrease its market value.

COURSE OF TREATMENT RECOMMENDED.

Self-boiled lime-sulphur, when properly applied, will entirely control peach scab, and when the curculio does not interfere too seriously it will largely prevent brown-rot. In view of the fact that numerous brown-rot infections take place through curculio punctures, it would seem advisable, where the two troubles occur together, to use arsenate of lead in connection with the lime-sulphur mixture as a

combined remedy for both troubles. The fact that arsenate of lead sometimes injures both the fruit and the foliage of the peach is well known and should be borne in mind by the orchardist, but when the applications are made early in the season the danger of injury seems to be slight. Therefore, upon the advice of Mr. A. L. Quaintance, of the Bureau of Entomology, arsenate of lead is included in the course of treatment outlined below.

BROWN-ROT, SCAB, AND CURCULIO TREATMENT.[a]

For the Elberta, Belle, Reeves, and other varieties of peaches of about the same ripening season, the following is advised:

(1) About the time the calyces (or shucks) are shedding, spray with arsenate of lead at the rate of 2 pounds to 50 gallons of water. In order to reduce the caustic properties of the poison, add milk of lime made from slaking 2 pounds of stone lime. The date of this treatment is too early for scab and ordinarily no serious outbreaks of brown-rot occur so early, so that the lime-sulphur may be omitted with reasonable safety; but during warm rainy springs, especially in the South, the lime-sulphur will doubtless be necessary in this application.

(2) Two to three weeks later, or about one month after the petals drop, spray with 8–8–50 self-boiled lime-sulphur and 2 pounds of arsenate of lead.

(3) About one month before the fruit ripens spray with 8–8–50 self-boiled lime-sulphur, omitting the poison.

For earlier maturing varieties, such as Waddell, Carman, and Hiley, the first two treatments outlined above would probably be sufficient ordinarily, but in very wet seasons bad-rotting varieties would doubtless require three treatments. Late varieties, such as Smock and Salway, having a longer season, would not be thoroughly protected by three applications, but on account of the expense the writers dislike to recommend a fourth spraying. In view of the results obtained on mid-season varieties it seems likely that three treatments will ordinarily be sufficient for the late varieties.

---

[a] The attention of the reader is called to the following statement by Mr. Quaintance regarding the use of arsenate of lead on the peach for the control of the curculio:

"The schedule of applications, arranged to effect a combination treatment for the plum curculio and brown-rot, represents a compromise as to the number of applications and times of spraying considered strictly from the curculio standpoint. Thus, were the control of the curculio the only consideration, the first application should be made within a week after the falling of the petals; the second about as the dried calyces, or "shucks," are being thrown off by the rapidly swelling fruit, and a third about two weeks later, though this latter treatment is attended with increased risk to the foliage and fruit.

"Of the several arsenical poisons, arsenate of lead should always be employed for stone fruits, especially the peach. There are now numerous brands of arsenate of lead on the market, and while most of these are carefully prepared and ordinarily free from dangerous by-products the grower should exercise care in the selection of a brand, purchasing only from reputable firms. Arsenical injury to peaches manifests itself by a shot-holing and dropping of the leaves and an excessive reddening and sometimes falling of the fruit as it approaches maturity. The extent of injury liable to result will depend upon weather conditions, and the number of applications given. Ordinarily, the risk from two applications of arsenate of lead, as outlined for use with the lime-sulphur mixture, will be inconsequential, and the orchardist can well afford to take the chances of injury in view of the great benefit derived in lessening brown-rot and in the control of the curculio itself."

BROWN-ROT AND SCAB TREATMENT.

In orchards where curculio is not troublesome, the arsenate of lead should be omitted. The treatment for brown-rot and scab on mid-season varieties would then be as follows:

(1) Three to four weeks after the petals fall spray with 8–8–50 self-boiled lime-sulphur.

(2) About three weeks later spray with the same mixture.

(3) About one month before the fruit is expected to ripen make another application of the same mixture.

SCAB TREATMENT.

For the treatment of scab alone, spray the trees with 8–8–50 self-boiled lime-sulphur about one month after the petals drop and again three to four weeks later.

One treatment thoroughly applied one month after the petals drop will so nearly control scab that in many cases a second spraying may not be necessary, but on account of the way spraying is ordinarily done two treatments will usually be required, especially on late varieties.

APPLICATION OF THE SPRAYING MIXTURES.

The necessity of keeping the mixtures thoroughly agitated while spraying can not be too strongly emphasized. Both self-boiled lime-sulphur and arsenate of lead settle readily, and if the spraying outfit is not equipped with a good agitator the mixture will not be evenly distributed and some of the trees will be oversprayed, while others will receive an insufficient application. In power sprayers the propeller type of agitator is the most satisfactory for this work. The early applications of lime-sulphur may be made rather heavy, but the last spraying should be made with fine nozzles, and the aim should be to give the fruit a uniform coating of a mist-like spray. Heavy drenching of the trees should be avoided.

PLATES.

DESCRIPTION OF PLATES.

PLATE I. Frontispiece. Peaches affected with brown-rot, showing the destructive work of the disease, the rotten, moldy appearance of affected peaches, and the gray tufts of spores produced by the fungus. This is a photograph of a pile of discarded Carman peaches in an orchard at Fort Valley, Ga.

PLATE II. Two crates of Elberta peaches picked from the experimental plats at Fort Valley, Ga., on July 9, 1909, shipped by refrigerator car to New York, and then by express to Washington, D. C., opened and photographed on July 16, a week after picking, showing the difference in the amount of brown-rot developed. The fruit on the left was from a sprayed plat, No. 6, and developed very little brown-rot, while that on the right was from an adjacent unsprayed plat and became badly affected with brown-rot in transit.

PLATE III. Peach scab. Fig. 1.—Two unsprayed Elberta peaches affected with scab, showing the black spots and cracks produced by the fungus. Fig. 2.—The crop of peaches from an unsprayed Elberta tree, showing the fruit badly affected with scab. All the fruit was affected and 86 per cent of it was so "smutty" and cracked as to be unfit for the market. This fruit was from one of the unsprayed trees in the orchard of the Sleepy Creek Orchard Company, at Sleepy Creek, W. Va.

PLATE IV. Peach scab. Fig. 1.—The crop of peaches from an Elberta tree sprayed once with self-boiled lime-sulphur. The good, merchantable fruit (98 per cent of the crop) is shown in the pile and the unmerchantable, scabby fruit on the notebook at the top. This fruit was grown in the same orchard as that shown in Plate III, figure 2. Fig. 2.—The same unsprayed crop shown in Plate III, figure 2, sorted for the market. The large pile of fruit on the right is unmerchantable on account of scab, that on the left representing all that was suitable or packing (only 14 per cent of the crop).

TWO CRATES OF ELBERTA PEACHES PICKED FROM THE EXPERIMENTAL PLATS AT FORT VALLEY, GA., ON JULY 9, 1909, SHIPPED BY REFRIGERATOR CAR TO NEW YORK, AND THEN BY EXPRESS TO WASHINGTON, D. C., SHOWING THE DIFFERENCE IN THE AMOUNT OF BROWN-ROT DEVELOPED.

The crates were opened and photographed on July 16. The fruit on the left had been sprayed, while that on the right had not been sprayed.

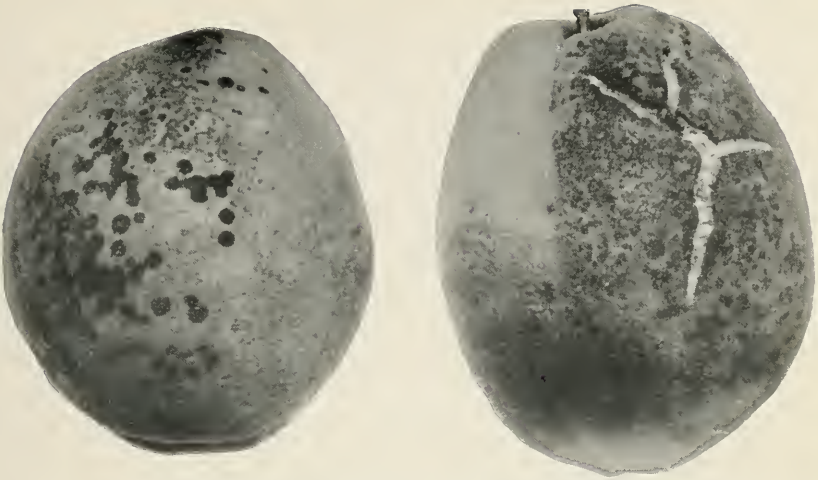

FIG. 1.—TWO UNSPRAYED ELBERTA PEACHES AFFECTED WITH SCAB, SHOWING THE BLACK SPOTS AND CRACKS PRODUCED BY THE DISEASE.

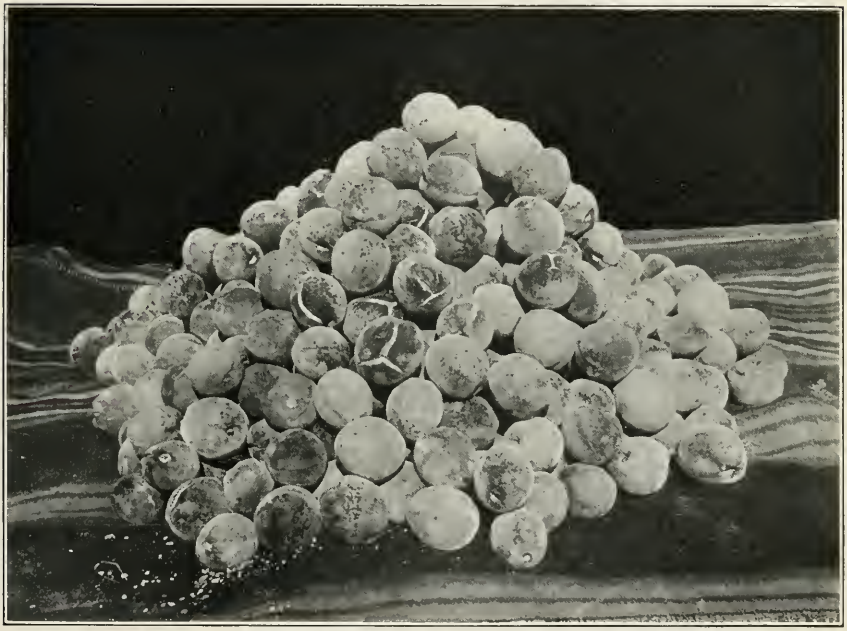

FIG. 2.—CROP FROM AN UNSPRAYED ELBERTA PEACH TREE, SHOWING ALL THE FRUIT AFFECTED WITH SCAB AND 86 PER CENT OF IT UNMERCHANTABLE. SLEEPY CREEK, W. VA., AUGUST 27, 1909.

FIG. 1.—CROP OF ELBERTA PEACHES FROM A TREE SPRAYED ONCE WITH SELF-BOILED LIME-SULPHUR. GOOD, MERCHANTABLE FRUIT IN THE PILE AND UNMERCHANTABLE, SCABBY FRUIT ON THE NOTEBOOK AT THE TOP. SLEEPY CREEK, W. VA., AUGUST 27, 1909.

FIG. 2.—THE SAME UNSPRAYED CROP SHOWN IN PLATE III, FIGURE 2, SORTED FOR THE MARKET. THE LARGE PILE ON THE RIGHT IS UNMERCHANTABLE, SCABBY FRUIT, THAT ON THE LEFT REPRESENTING ALL THAT WAS SUITABLE FOR PACKING.

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BUREAU OF PLANT INDUSTRY—BULLETIN NO. 175.
B. T. GALLOWAY, *Chief of Bureau.*

THE HISTORY AND DISTRIBUTION OF SORGHUM.

BY

CARLETON R. BALL,
AGRONOMIST IN CHARGE OF GRAIN-SORGHUM INVESTIGATIONS.

ISSUED APRIL 8, 1910.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1910.

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BUREAU OF PLANT INDUSTRY—BULLETIN NO. 175.

B. T. GALLOWAY, *Chief of Bureau.*

THE HISTORY AND DISTRIBUTION OF SORGHUM.

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CARLETON R. BALL,
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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., December 18, 1909.

Sir: I have the honor to transmit herewith a paper entitled "The History and Distribution of Sorghum," by Mr. Carleton R. Ball, Agronomist in Charge of Grain-Sorghum Investigations, and recommend its publication as Bulletin No. 175 of the series of this Bureau.

The facts stated in the paper have been developed in connection with a study of the agronomic adaptations of over 1,000 varieties of domestic and foreign sorghums. Data concerning the geographical distribution of the sorghum plant and the leading types which are found in different regions of the earth are here presented for the first time. Sorghums have been very extensively used as human food in Africa and the Orient for more than twenty-five centuries. Some of them are now important grain and forage crops in large areas of the western United States, and have been found adapted to a much wider range of climatic and soil conditions than was formerly thought possible. A knowledge of their distribution and adaptations in their native lands will be of value to all agronomic workers and others concerned in the improvement of these crops.

The author wishes to acknowledge his obligation to Miss R. M. Kolck for assistance in the translation of the Latin works; to Miss A. R. Knapp for the translation of the Italian article by Arduino; and to Miss M. F. Warner for aid in securing and citing many old and rare botanical works.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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THE HISTORY AND DISTRIBUTION OF SORGHUM.

INTRODUCTION.

Certain sorghums now hold a large and increasingly important place as grain and forage crops in the semiarid regions of this country. They were all introduced into the United States between twenty and thirty years ago. Few data were secured concerning their habits and adaptations in their native lands, and many valuable years of time and effort were lost in attempts to grow them successfully in regions to which they were not at all suited.

During the past six years more than 1,200 different lots of domestic and foreign sorghums have been brought together and grown experimentally. By far the greater part of these were from foreign sources—principally from Africa and southern Asia. In most cases only meager information was obtained regarding the conditions under which they had been grown or to which they are most probably adapted in this country. For these economic reasons and because of the bewildering diversity of forms secured it became necessary to inquire at some length into the whole question of the origin and history of this group of cultivated plants. This paper embodies the results of the investigation. The origin and antiquity of sorghums are set forth, together with their present distribution and culture. The chief types or groups now found in each of the major geographical areas are briefly described, the conditions under which they have developed are pointed out, and their probable adaptations in our own land are indicated.

The term "sorghum" is used here in the broad and comprehensive sense. It thus includes all the groups popularly known in this country as sorgo or sweet sorghum, kafir, broom corn, shallu, kowliang, durra, and milo. It covers also an enormous number of cultivated forms in other lands with the possible exception of a few, which, as pointed out in the discussion of botanical history, may perhaps be referred to *Andropogon halepensis* rather than to *A. sorghum*. For the convenience of readers not familiar with the sorghums, a rather

full key to the principal groups is inserted here. A complete classification of the domestic varieties is in preparation.

KEY TO THE PRINCIPAL GROUPS OF SORGHUM.

The following is a key to the principal groups of sorghum:

I. Pith juicy.
  A. Juice abundant and very sweet.
    1. Internodes elongated; sheaths scarcely overlapping; leaves 12–15 (except in Amber varieties); spikelets elliptic-oval to obovate, 2.5–3.5 mm. wide; seeds reddish brown. I. *Sorgo.*
  B. Juice scanty, slightly sweet to subacid.
    1. Internodes short; sheaths strongly overlapping; leaves 12–15; peduncles erect; panicles cylindrical; spikelets obovate, 3–4 mm. wide; lemmas awnless. II. *Kafir.*
    2. Internodes medium; sheaths scarcely overlapping; leaves 8–11; peduncles mostly inclined, often recurved; panicles ovate; spikelets broadly obovate, 4.5–6 mm. wide; lemmas awned. VII. *Milo.*

II. Pith dry.
  A. Panicle lax, 2.5–7 dm. long; peduncles erect; spikelets elliptic-oval or obovate, 2.5–3.5 mm. wide; lemmas awned.
    1. Panicle 4–7 dm. long; rhachis less than one-fifth as long as the panicle.
      a. Panicle umbelliform, the branches greatly elongated, the tips drooping; seeds reddish, included. III. *Broom corn.*
    2. Panicle 2.5–4 dm. long; rhachis more than two-thirds as long as the panicle.
      a. Panicle conical, the branches strongly drooping; glumes at maturity spreading and involute; seeds white or somewhat buff. IV. *Shallu.*
      b. Panicle oval or obovate, the branches spreading; glumes at maturity appressed, not involute; seeds white, brown, or reddish. V. *Kowliang.*
  B. Panicle compact, 1–2.5 dm. long; peduncles erect or recurved; rhachis more than two-thirds as long as the panicle.
    1. Spikelets elliptic-oval or obovate, 2.5–3.5 mm. wide; lemmas awned. V. *Kowliang.*
    2. Spikelets broadly obovate, 4.5–6 mm. wide.
      a. Glumes gray or greenish, not wrinkled; densely pubescent; lemmas awned or awnless; seeds strongly flattened. VI. *Durra.*
      b. Glumes deep brown or black, transversely wrinkled; thinly pubescent; lemmas awned; seeds slightly flattened. VII. *Milo.*

AGRICULTURAL HISTORY AND DISTRIBUTION OF SORGHUM.

ORIGIN.

It is generally conceded that cultivated sorghums were originally derived from the well-known wild species, *Andropogon halepensis* (L.) Brot. Prof. E. Hackel (1885) has presented this theory at length, and it is not necessary here to examine his able argu-

ment. The wild species is found abundantly in all tropical and subtropical parts of the Old World (fig. 1). It has been quite carefully studied by agriculturists and botanists in India, and to a lesser extent in tropical Africa. Its forms are numerous and the

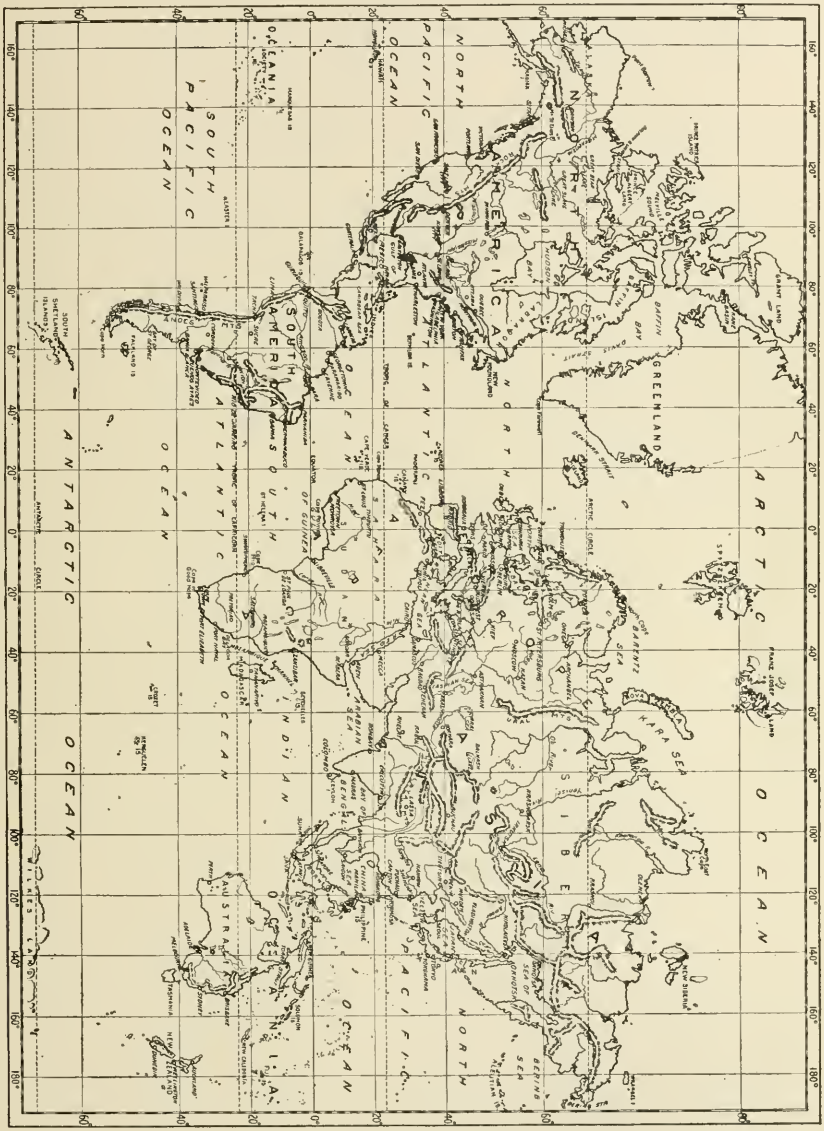

FIG. 1.—Map of the world on Mercator's projection.

main lines of variation are parallel with those represented by the major groups of cultivated varieties. This is especially noticeable in comparing the forms assumed by the wild and the cultivated species in Africa, and to a lesser extent in India also. The abundant

variation of the wild species, the great number of different cultivated forms, and, with few exceptions, their evident dissimilarity in the two regions argue for the independent origin of the cultivated species on the two continents. This view has gained wide acceptance in later years. In the discussion of geographic distribution this theory is recognized as the probable one.

ANTIQUITY.

There can be no doubt of the great antiquity of the sorghum plant in cultivation. The story of its domestication is lost in the shadows of the past. From Egypt, the cradle of ancient agriculture, comes the earliest known record of its use. A harvest field frescoed on the walls of the tomb of Amenembes in Beni-Hassan, belonging to a dynasty existing at least 2,200 years before Christ, is said by Wönig[a] (1886) to represent a form of sorghum. This crop is still important in the land of the Nile. In the book of the prophet Ezekiel (600 B. C.) the word "millet" is translated "dochan" ("dochn" or "dokhn") in the original Hebrew text. This word is still used in Arabic for forms of sorghum and also for some of the larger millets, such as pearl millet (*Pennisetum spicatum*). The root word also means "smoke" in Arabic, and the name may be more correctly applicable to pearl millet, with the seeds sometimes smoke colored, than to sorghum. If it here refers to a grain-bearing sorghum, this crop was well known in the fertile and irrigated valleys of the Tigris and Euphrates more than 600 years before the present era. It is known that a sorghum with white and flattened seeds was cultivated in Arabia as early as the tenth century. A very similar white durra is still abundantly grown in Syria and Mesopotamia, and forms a considerable part of the food of the poorer classes.

Little light can be thrown on the early history of sorghum in India. The Roman historian Pliny records the introduction of sorghum into Italy by caravans from India during the first century. How much longer it had been cultivated in India is not certain, nor can we be entirely sure that the record of the Roman historian is correct. Caravans coming from India then, as now, passed through Upper Egypt, and the sorghum supposedly brought from India may possibly have been an Egyptian variety used as food in the last stages of their journey. The great antiquity of sorghum culture in India is, however, assured from other sources. According to Benson and Subba Rao (1906), the plant is mentioned in one tale dating from more than 1,900 years ago. It is spoken of by many other writers of early times and bears a Sanskrit name—Yava-nala (reed barley or reed grain).

[a] Where only year and page are given, see chronological bibliography at end of bulletin for full citation.

It is very extensively cultivated, with a multitude of varieties and names, throughout the major part of India, especially in the interior in native states, which have had only a limited intercommunication. There are some important religious ceremonies observed in connection with its sowing and harvesting. These facts all point conclusively to its cultivation there from a remote period.

In China there is evidence, according to Bretschneider (1893), that sorghums were first known there in the third century A. D. There are numerous doubtful references of earlier date which may apply either to sorghum or to the true sugar cane. As early as some of the ancient classics there is found mention of a black millet which bore two seeds in each spikelet. So far as the writer is aware, there are no two-seeded varieties known either in *Panicum miliaceum* or in *Setaria* (*Chaetochloa*) *italica*. Several varieties of what may be called "twin-seed" sorghums are known in India. Some of these have black and shining glumes, and it is quite possible that the writer of the ancient classics referred to such forms of sorghum. This is the more probable since it is most likely that China received her sorghum varieties from some part of the Indian Empire.

These isolated records all indicate an early and extensive domestication of this plant. The same conclusion may be deduced from a study of the present distribution of the cultivated varieties.

GEOGRAPHICAL DISTRIBUTION.

Originating in the Tropics of the Old World (fig. 1), sorghums are now grown in the Temperate Zones of both hemispheres. The bulk of the crop is grown between the parallels of latitude 40° north and south. In the United States and in Manchuria the sorghums are found as far north as latitude 45° or more. The two great centers of the cultivation of sorghum for human food are Africa and India. In both regions it is the staple farinaceous food for a considerable part of the population. The distribution of sorghum in India is discussed in its proper order. A word on some of the general aspects of its occurrence in tropical Africa (fig. 2) may be in order before the discussion of individual regions is begun.

The absence of permanent records among the African tribes from the Sahara southward nearly to the Cape makes futile any attempt to study the history of sorghum among them. For many tribes it is, however, the most important food plant and is also commonly used in the manufacture of a fermented drink. The widespread dispersion and cultivation of sorghum among these tribes and their great dependence upon it for food point to its ancient origin and domestication. Still more striking testimony is the extreme richness of the varieties and forms which it presents. These are by no

means adequately known, but it seems likely that they will easily outnumber the combined total from all other parts of the world. Most of them belong apparently to groups which are found sparingly or not at all elsewhere. Such a profusion of forms of a cultivated plant among primitive peoples must have required many centuries for derivation and development. Not only the names, but the actual varieties also are often quite different in separate, though adjacent,

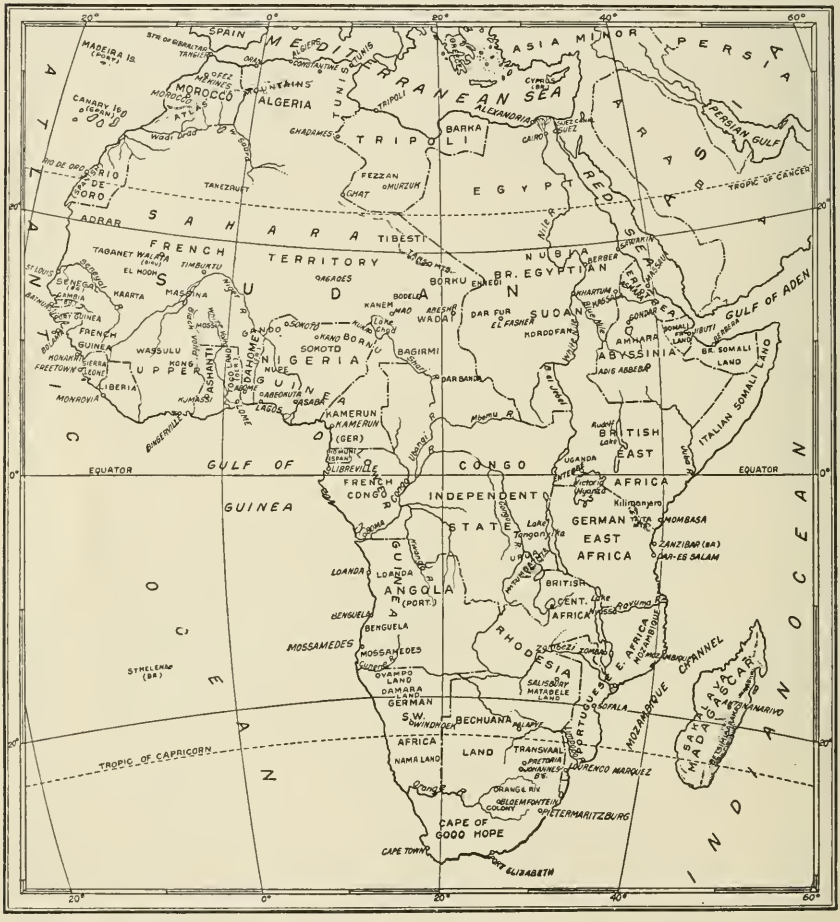

FIG. 2.—Map of Africa. (Scale 1,200 miles to the inch.)

tribes. The women of a tribe, who are commonly its laborers, often become quite expert in distinguishing closely related varieties—a knowledge to which the men seldom attain. Their methods of cultivation are necessarily crude, but through the accumulated wisdom of many centuries of cultivators they have amassed a great deal of accurate information about the handling of the crop. How it responds on different soils and in different seasons, the proper dis-

tances for planting the hills of different varieties, how and when to harvest, and how best to cure the seed, as well as considerable skill in preparing different articles of food from it, are matters of common knowledge among the older members of various tribes. Of the numberless varieties grown by tribes throughout the length and breadth of tropical Africa, only the sweet sorghums and kafirs from the region of Natal and the Orange River Colony have ever been brought under cultivation in this country.

South Africa.

That portion of the great tropical continent known as South Africa includes the British areas of Cape Colony, Natal, Orange River Colony, Transvaal, and Rhodesia; also German Southwest Africa and parts of Portuguese East Africa and the Portuguese territory of Angola on the west coast. It is not known if sorghums are grown in the German and Portuguese territory on the west side and little is known of the varieties found in Portuguese East Africa. The forms of British South Africa have been quite fully studied. Much of this area is a more or less dry and elevated plateau, an ideal place for sorghums. Two of the principal groups, sorgos (sweet sorghums) and kafirs, are found here in the greatest abundance and diversity. They require but little selection to make them suitable for use in America because of the similar conditions obtaining in the two regions.

Natal.

Natal, the smallest division of South Africa, lies in the southeastern part of this great region, its coast washed by the Indian Ocean. Only two sorghum groups, sorgos and kafirs, appear to be native to this little state or extensively grown therein.

In Natal the sorgos are cultivated by the natives for forage and for the sweet juice, which they express by chewing the peeled stalks. It was from Natal that sorgos were introduced to Europe and America. From Natal, Arduino obtained, about 1775, his *Holcus cafer*, which was apparently very similar to our Planter sorgo. From Natal, Wray secured, in 1853, the sixteen saccharine varieties from which have descended most of the sorgos now cultivated in Europe and the United States. Several importations of sorgo varieties were made from Natal in later years, but no systematic comparison of the resulting plants was ever undertaken. It is therefore not known how many different varieties have been found there up to the present time. Some varieties recently obtained are proving distinct from any forms now grown in this country.

The kafir group is probably native in Natal, though the varieties first domesticated in America were brought from the Orange River Colony. Within the past few years forms very similar to our blackhull and red kafirs have been secured in Natal. With these have come a number of other forms varying mostly in the size of the head and

in the size and color of the seeds and glumes. Some forms of the Roxburghii group are occasionally found in Natal, but are apparently introduced from Madagascar, from the regions north of the Zambezi River, or from India.

FIG. 3.—Heads of four kafir varieties. *a*, White kafir; *b*, Guinea kafir; *c*, blackhull kafir; *d*, red kafir.

ORANGE RIVER COLONY.

Our widely grown and valuable kafir varieties came from the former Orange Free State about thirty years ago. From that first importation three varieties resulted, the white, the blackhull, and the red kafirs (fig. 3), of which only the last two are now cultivated in

the United States. Recent importations from British South Africa, principally from this colony and Natal, reveal the presence of a great number of similar forms throughout the eastern portion of South Africa. They are all undoubted kafirs, differing from our three varieties in minor details, such as size and height of the stalk, length of the head, and size and color of the seeds and glumes. Many of these forms have larger seeds than had the forms first imported. No new colors in seeds have been found, but only varying shades of red and pink. Their variation in much more narrow limits than the sorgos may indicate a more recent origin.

FIG. 4.—Plants of shallu, representing the variety roxburghii, Hackel.

TRANSVAAL AND RHODESIA.

A few kafir forms have recently been obtained from the colonies of Transvaal and Rhodesia. It is probable that when northern Rhodesia has been more fully explored that varieties similar to those of equatorial Africa will also be found.

MADAGASCAR.

The large island of Madagascar, more than a thousand miles long, lies off the east coast of South Africa at a distance of 300 to 500 miles. Its sorghums are naturally not well known, but the few that have been obtained, under the native name of Mpemby, are freely stooling and very leafy sorts, with loose open heads bearing white or reddish-brown seeds. The panicles vary much in shape, some being oblong or narrowly oval, others short and fan shaped, while still others are much elongated and trumpet shaped. The branches of the head are always long, slender, repeatedly divided, and often drooping. (Fig. 4.) The spikelets are slender, acute, and prominently

awned. These forms belong, apparently, to the variety *roxburghii* Hackel, together with the shallu of India and some of the forms of the Guinea coast, under which heading this form is more fully described. Similar forms are found occasionally in Natal, where they are apparently introduced rather than native. All these varieties are very late and are apparently adapted only to our Southern States, if at all.

Equatorial Africa.

But little is known of the sorghums of equatorial Africa, an immense region which includes roughly about ten degrees of latitude on either side of the equator. They seem to be but little grown in the French and German Kameruns on the west coast. Almost nothing is known of their occurrence in the great interior Kongo State. On the east side, however, it is known that the sorghums occur in extremely numerous and variable forms.

German and British East Africa.

A considerable number of sorghums have been secured from German East Africa and British East Africa, lying immediately south and north of the equator, respectively. Naturally they have not matured at any of our testing stations in this country, and hence there has been but little opportunity to study them fully at first hand. Many of them certainly represent entirely new groups of sorghum. One of the most promising of these groups stands in some respects in a position intermediate between the sorgos and durras. Some of the varieties represent a northward extension of the kafir group. All are grown for human food and for forage.

Sudan.

The Sudan has a breadth north and south of about 1,000 miles and an extension east and west of about 4,000 miles. It includes, in its western part, the French Sudan and the numerous small colonies of the Upper Guinea coast. The principal ones of these are, from west to east, Senegal and French Guinea, once known as the Kerry Coast; Sierra Leone and Liberia, the old Grain Coast; the Ivory Coast, now a French colony; the Gold Coast, now a British colony; and finally Togoland, Dahomey, and Nigeria—German, French, and British colonies, respectively, together comprising the Slave Coast. The eastern part of the Sudan is included in the British-Egyptian Sudan, to the east of which lies Abyssinia. The coastal region is tropical and humid, the interior in large part hot and with little rainfall.

French Sudan.

Very few sorts have yet been obtained which are known to have come from the interior of the French Sudan. These few do not differ, so far as can be determined by the seeds and glumes, from

the groups found farther south in the various colonies of the Guinea coast. However, it seems not improbable that more extensive exploration may discover, in the dry, hot territory forming the southern border of the Sahara, other varieties adapted to our western plains.

UPPER GUINEA.

Varieties have been obtained from Senegal, French Guinea, Ivory Coast, Gold Coast, Togoland, Dahomey, and Nigeria. The leading group is one with large, oval, flattened seeds, varying in color from white through pale red to deep reddish brown: red, brown, or black glumes, and semicompact heads. A striking peculiarity is the lateral rotation of the seed in the glumes at maturity, the axis of the movement being a line from the hilum to the apex of the seed. This movement of the seed is apparently characteristic of the whole group, which includes Hackel's variety *oculifer* and probably some other botanical varieties. The different forms in this group all have the appearance of being good grain producers. An effort should be made to find some suitable for cultivation in this country. Those heretofore secured are much too late for any but tropical regions.

Another sorghum group found in this region is closely related to the shallu (fig. 4) of India, and probably represents Hackel's variety *roxburghii*. It is characterized by rather slender stalks, loose, open, pyramidal heads with more or less drooping branches, small, oval seeds, and slender, acute glumes, which spread apart and become involute at maturity, completely exposing the seeds. One of these varieties from Senegal, called by the French "Mil Cigne," is apparently meeting with some favor at the Florida Agricultural Experiment Station. It seems adapted as a combined forage and grain crop.

BRITISH-EGYPTIAN SUDAN.

A recent importation of several varieties from the region of Khartum shows that the leading varieties are of the durra type found in Lower Egypt, some of the varieties being identical. The seeds average smaller, but this may be due to the less luxuriant growth of the Sudanese plants. Besides the usual forms with white, pale-yellow, and pale-brown seeds, there is one with gray seeds. This last variety has proved quite early and a fair yielder, and may ultimately become a profitable crop in the United States. The seeds tend to become white under our climatic conditions. The other varieties are now being grown for the first time, and their maturity will be watched with interest in the hope of finding some of value.

ABYSSINIA.

The sorghums of Abyssinia are yet but little known. In a considerable collection of the seeds sent from that country to France in 1840

it is reported that a large number of varieties was found. Some of them were full of very sweet juice, some but slightly sweet, and others not at all so. Their other varietal characteristics were not indicated. Very meager data have accompanied the few shipments of seed received in this country from Abyssinia. Most of the varieties are apparently very late, and only occasionally can one be brought to the flowering stage, and none to maturity, in the United States. Most of them are very tall and stout (fig. 5) and of apparent kinship with the larger varieties of India. Some are shorter and freely stooling, though with stems of enormous size. The mixed seed in one lot are apparently identical with those of the yellow and brown durras (safra and ahmar) of Egypt. Many of the sorts introduced have apparently been badly hybridized. None of them give promise of being of any value, unless for silage and fodder on the Gulf coast. Since the interior of Abyssinia is a high and dry plateau, it may be that varieties suitable for our high plains will yet be discovered there.

FIG. 5.—Plants of an Abyssinian sorghum not yet headed.

NORTH AFRICA.

Northern Africa may be separated into two regions, in each of which sorghums are grown to a considerable extent for human food.

These regions are (1) Egypt and (2) the Barbary States. The varieties found in each are different, and also differ from those of equatorial Africa.

EGYPT.

In Egypt, durra is used as a general term to designate all succulent forage. All sorghums are called durra beladi to distinguish them from corn, durra shami. The fall-sown sorghum is called nili and the spring-sown, or common crop, sefi. The varieties with erect heads are called aym, those with pendent heads awagi. There are three sorghum varieties in common cultivation, all belonging to the spring-sown crop with erect heads, or the durra beladi sefi aym. The three are known as beda, or white seeded; safra, or yellow seeded; and ahmar, or brown seeded. Beda is grown more extensively than all the others combined. Where grown in this country all three are very tall and very stout forms of the durra group, 10 to 14 or more feet in height, with 20 to 30 leaves on each stalk. All possess larger seeds and more closely compact heads than are found in any other varieties of the durra group. They are of no apparent value for any part of the United States.

It is possible that safra, the yellow-seeded variety, was the foundation stock for the milo of this country. They are very much alike in both glume and seed characters, including the awns. These Egyptian forms, while larger in the size of plant and seed, are rather similar to some forms from Abyssinia and from India. The probable relationships of these sorts are more fully discussed under the heading "Botanical history." The groups of sorghum so common in central and southeastern Africa are not found in Egypt, with the exception of an occasional kafir in Upper Egypt, an evident stranger from the South.

BARBARY STATES.

In Morocco, Algeria, Tunis, and Tripoli, comprising the Barbary States, the leading variety of sorghum is a white durra (fig. 6, *b*), called bechna, or beshna, by the Kabyles of Algeria. It is practically identical with that introduced into this country as Egyptian corn, known later as rice corn, and more recently as Jerusalem corn. It is probably not indigenous to North Africa. A very similar white durra is found throughout Turkestan, Mesopotamia, Syria, and Arabia, and the North African plant is probably a result of the Arab invasion of that region in the third century. There is also found sparingly among the mountain tribes, or Kabyles, of Algeria and in certain oases in the northern Sahara a red-seeded durra very similar to our brown durra and very likely the original form of it. This form has not yet been found in Arabia or elsewhere in southwestern

Asia. The physical and climatic features of the two regions are quite similar, and the almost complete absence of any other forms has prevented much hybridization. For that reason there has apparently been but little change in the varieties in many centuries.

The climate of much of this North African region is dry and hot. The white durra when grown in our Western States is very early and drought resistant and likewise a fair yielder. Its chief faults are the pendent heads of most strains and the freely shattering seeds. The shattering habit does not seem to yield to continued selection. If a strictly nonshattering strain could be found in North Africa, it would be of great value for our higher altitudes and latitudes. The brown durra is an inferior sort and gives little promise, though it is also early and able to grow with little moisture.

FIG. 6.—Plants of white durra from different countries, showing varying characters. The stalks in pairs, from left to right, are from (*a*) the United States, (*b*) Algeria, (*c*) Austria, (*d*) Turkestan, and (*e*) Syria, respectively.

SOUTHWEST ASIA.

White durra, the single variety found throughout the region of Asia Minor, Russian Turkestan, Syria, and Arabia (see fig. 6), has already been mentioned. In the southern part of this area it has certainly been grown for nine centuries, and probably for three times that period. The form commonly grown in these lands differs from that of North Africa and the United States in having the heads shorter and more compact and the seeds smaller, less flattened, and with less tendency to shatter. The heads of nearly all strains are persistently pendent or goose necked. In parts of this region the white durra grows under exceedingly high summer temperatures. It is possible that very drought-resistant strains may be secured here. However, those brought from this region heretofore have not seemed to be more especially drought resistant than our best developed strains of kafir and milo. A nonshattering form of white durra from a dry, hot region would be of great value on our dry and windy plains.

The land tax levied by the Turkish Government is paid by the natives in the seed of this white durra. The people are required by the officials to present in such payments cleaned and selected seed, much better than the average found on the market or used in their homes for food. No other sorghums are found in all this great region except occasionally a little Amber sorgo introduced from Europe or America.

India.

In the number of varieties of sorghum and the relative importance of the crop, India ranks second only to tropical Africa. The total area grown in India and Burma is now about 25,000,000 acres annually. Though cultivated for many centuries and forming a staple and very important article of human food and of export, Indian varieties have apparently not been selected or improved for grain production. The average grain yield obtained there would be considered very small in this country. According to the best statistics obtainable by the British Government and published recently, 10 bushels to the acre would seem to be a fair average for the grain yield of sorghum in India. Methods of cultivation are crude, and losses by drought, fungi, insects, and birds are considerable. It does not appear that the soil is especially poor, in spite of centuries of cultivation. This may be largely due to an abundant use of legumes, both as staple crops and as fillers or subordinate crops.

As noted, the number of varieties is very large. They vary in the different native states, and the names applied to them are much more numerous and variable than the forms themselves. Many of the varieties would be classed as durras, though none is identical with any of our cultivated durras. In color the seed of most of them is white or pearly yellowish, but in a few it is red. The heads, and the seeds as well, average quite small, though the plants themselves are usually both tall and stout (fig. 7). This is probably explained by the fact that in India the plants are always grown for both fodder and human food. Owing to their large size they are inclined to be rather late in maturing. A few varieties are dwarf in height, but these also have stout stems and mature with us scarcely earlier than the others. Rather compact heads and firm glumes are characteristic. One or two very large varieties are two seeded: that is, they have two fertile flowers and produce two seeds in each spikelet, instead of one, as is normal for the sorghums.

From more than 300 different lots of Indian origin, which have been studied by the writer, only one or two have seemed worthy of attempts at improvement. The small size and hard nature of the seeds would necessitate grinding to make them profitably available as stock food. To eliminate the large size of the stalk and bring the grain yield up to a profitable quantity would require several years

of careful selection. There is nothing in the appearance of the varieties to indicate that at the end of this period one might hope for anything better than, or even equal to, the best kafirs, white durra, and milo which we now possess. It should be possible to secure some excellent early and drought-resistant varieties in India by searching through the middle and northern parts of the Empire, as Berar, the Central Provinces, the United Provinces of Agra and Oudh, north to the Punjab and the frontier. Those previously introduced have come from the Madras and Bombay Presidencies.

Besides the durra-like forms, there are a few minor groups, of which only one needs special mention here. In all the writings on Indian agriculture concerning the sorghum crop there are references to a fall-sown, or rabi, crop. The great bulk of sorghums in India, as elsewhere, is sown in the spring and harvested in the summer or

FIG. 7.—Plants of different varieties of sorghum from India.

autumn. The rabi crop, on the contrary, is sown in September or October and harvested in the following February or March. From all available information this rabi crop is mostly composed of a single variety or group of very similar varieties, which is commonly called "shallu," or "shalu." Botanically these forms represent the variety *roxburghii* Hackel. The rabi crop is most largely grown in the Bombay Presidency, although not unknown in other sections of India. The shallus are characterized by rather slender stems, large, loose, and open panicles, and oval yellowish or straw-colored spikelets. The two indurated (empty) glumes spread wide apart at maturity and each becomes involute, thus leaving the white or pearly seed fully exposed. One variety of this group has been sparingly cultivated in our lower Plains region for several years and is now being carefully tested as a grain sorghum. (See fig. 4.)

A saccharine, or sirup-bearing, variety of sorghum is said [a] to have been largely grown locally for a long time at Bikanir, a point in northwest India, but seed of it has not yet been secured. A few saccharine varieties were introduced from this country into India thirty or more years ago, but did not prove popular in a country where the same variety is expected to supply both human food and animal forage. Amber and Collier sorgos, more or less pure, are still found there locally in very limited quantities.

The large varieties of Abyssinia seem to be very similar to, if not identical with, some of the larger India varieties, so far as one may judge from immature specimens of Abyssinian plants. Commercial intercourse between India on the one hand and Egypt and Abyssinia on the other has always been very free, and it would be surprising indeed if there had not been an interchange of the commonly cultivated crops. This may explain the similarity of some forms in the two regions.

There is abundant and quite conclusive evidence that cultivated sorghums have originated independently in India and in Africa. *Andropogon halepensis*, the presumable parent form, is abundantly distributed and highly variable in India. In some sections it is sparingly cultivated. In times of famine the seeds of this wild species are generally utilized for food. It has been suggested by agricultural writers of India that some of the forms now cultivated have been so recently and directly derived from *Andropogon halepensis* that they may still be referred to it rather than to *Andropogon sorghum*.

China.

In China sorghum is called "kowliang" (fig. 8), or "tall millet," to distinguish it from the various smaller millets, species of Panicum and Chaetochloa (Setaria). All the forms studied by the writer, except the single saccharine variety, belong to a single related group of sorghums, which will henceforth be called the "kowliang group." Three varieties used as food have been distinguished: Brown kowliang, the most common one, with brown seeds and black glumes; blackhull kowliang, with white seeds and black glumes; and white kowliang, with white seeds and pale or greenish glumes. The stems are slender, usually quite dry and pithy, 4 to 11 feet in height, with oblong, somewhat open panicles 6 to 12 inches in length. Most of the strains secured have very tall stems, due apparently to the need of the Chinese to obtain as much fodder and fuel as possible with the grain. While none of the introduced strains are heavy yielders of grain, some of the dwarf forms are extra early and promise to be valuable as grain crops on our high plains if their productiveness can

[a] Watt, 1893, p. 283; 1906, p. 111.

be sufficiently increased. A brown-seeded form with the panicle branches elongated is used for brooms and brushes.

This group is apparently confined to the northeastern part of China proper and to adjacent Manchuria, from latitude 38° to 41° north. In this region it is very important. The seed is used for human food, the stems and leaves for fodder, thatching, fences, and baskets, and the stems and roots for fuel. Since *Andropogon halepensis* is not native in this portion of China, there is little probability of a Chinese origin for the kowliangs. They are not like any varieties so far found in India or in any other country. These facts seem to point to their introduction into China many centuries ago and their subsequent modification to the present forms. Since authentic references to a sorghum are found in Chinese literature at least as early as the third century A. D., this theory seems the most probable one.

FIG. 8.—Plants of two varieties of kowliang from China.

In 1851 the seed of a variety of sorgo or saccharine sorghum was sent to France from the island of Tsungming (Chungming) in the mouth of the Yangtze River, latitude 32° north. From the brief and unsatisfactory descriptions and illustrations (fig. 9) of it published in France and in this country, we know that it had a tall and slender stalk, with about thirteen leaves, and a loose, conical panicle, with more or less drooping branches, and light-brown seeds completely enveloped in shining black glumes. These characters show that it was very similar

to some of our forms of Amber sorgo. Our Early Amber is said to have originated in 1859 as a sport in a field of Chinese sorgo growing in Indiana.

No other saccharine variety has been found in China. This one is said by Collins[a] to be almost entirely restricted to the island of Tsungming, where it is cultivated as a delicacy for the Shanghai market, the sweet stems being eaten raw. The annual area sown on the island is only about 20 acres. Since the original importation in 1851 no seed, except that sent by Collins, was ever brought to the United States until May, 1908, when a few seeds (S. P. I. No. 22913), secured on the island of Tsungming, were received by the Office of Seed and Plant Introduction of this Department. These seeds were of poor quality and the resulting plants did not fully mature, but are apparently identical with some forms of Amber now grown in this country. There is, however, little doubt of the independent African origin of some Amber forms.

FIG. 9.—Plant of Chinese sorgo. (From Patent Office Report, 1854.)

That form of kowliang which somewhat resembles broom corn is found also in Korea and Japan. It would be classed as very poor brush in the United States. Some improved broom corn is grown in Japan, but it is probably from seed originally secured in Australia, Europe, or the United States.

PACIFIC ISLANDS.

The tropical islands of the Pacific show very few sorghums or none at all. Some of the larger islands, like Java, lying near the

[a] Collins, 1865, p. 91.

continent of Asia, have one or two varieties, apparently of Indian or American derivation. In Australia the standard varieties are all importations from the United States. Numerous native varieties from India and the British colonies in Africa have been tested in Australia recently and a few are likely to persist in cultivation, at least for some years.

EUROPE.

Pliny (70 A. D.) records that a variety of sorghum was introduced from India into Italy about ten years previously. Its cultivation in Italy has apparently been continuous since the earliest introduction, and it was there that the name surgo, or sorgo, was first applied to the crop. In the extensive commerce of Greece and Rome with Africa and Asia it is probable that other importations of sorghum reached the northern shore of the Mediterranean Sea from time to time. By the end of the fifteenth century the cultivation of one or more forms of sorghum had become quite general in all of southern Europe from Greece to Portugal. It had also gradually extended northward to Germany (fig. 10), France, Belgium, Holland, and even to England. In these more northern countries it was probably grown as a curiosity in botanic gardens and did not always mature. It was generally known as Indian millet or reed millet to distinguish it from the smaller millets.

FIG. 10.—Plant of sorghum, after Fuchs, 1542.

In southern Europe the seed at that time had come into common use for fattening pigeons and poultry and less commonly other stock. The forage, both green and cured, was used for various kinds of cattle, though it was early noted that animals sometimes died after grazing on the living plants. The seed was also commonly used in the making of bread by the poorer, or peasant, classes. This bread was brittle, dark colored, and more or less astringent. It was generally regarded as inferior in nutritive qualities to that made from the other millets, as *Panicum miliaceum* and *Chaetochloa* (*Setaria*) *italica*, or that from the larger cereals. The flour was also commonly made into a porridge with milk. The semisweet pith and sometimes the flowers were used in medicine.

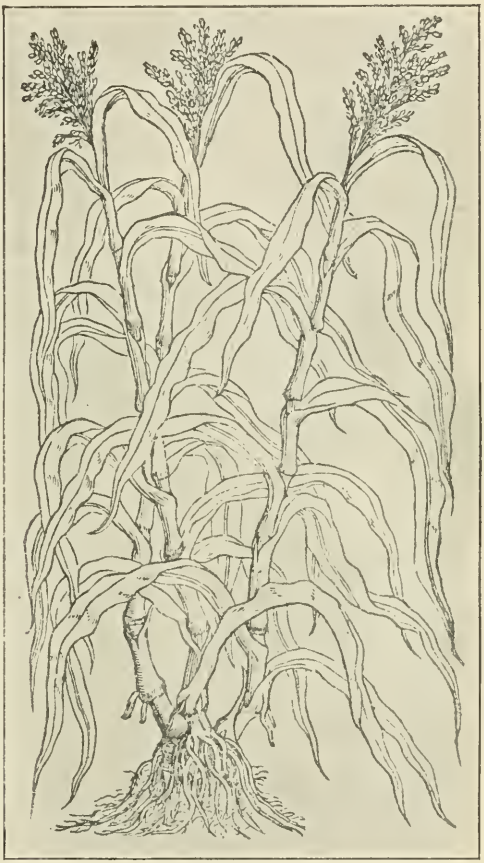

FIG. 11.—Plant of sorghum, after Dodoens, 1583.

The development of a broom corn from some loose-panicled sorghum took place in Italy more than two hundred and fifty years ago. Caspar Bauhin in 1658 states that the slender and very rigid dried heads were made into brooms by the Italians and used for brushing clothing in Italy, France, and also Germany. Ray in 1688 gives a full discussion of sorghum and records this use of the plant, stating that he himself had seen such brooms on sale in Venice. From just what form of sorghum this selection took place can never be known, but in figure 11 a loose-panicled form is shown, first pictured by L'Obel in 1576 and copied by Dodoens. Arduino in 1786 figures one more spreading than our Amber sorghum (fig. 12) and another with the rhachis much shortened (fig. 13), either of which would have been an excellent basis for broom-corn selection.

The form introduced into Europe during Pliny's time seems to have been on the order of the sweet sorghums, even though it is not known to have had a sweet juice. It is noted as having stout culms, 7 feet high, and abundant black seeds, the color doubtless referring to the inclosing glumes. Most sixteenth to eighteenth century writers who mention these details describe this sorghum as having reddish seeds and black glumes, with culms from 7 to 10 feet or more in height and heads about 9 inches long. Many writers from the tenth to the eighteenth century describe also the white-seeded sorghum used by the inhabitants of Asia Minor, Arabia, and Mesopotamia, but none records its introduction into Europe. All references to its growth in Cicilia, or Sicilia (Sicily), are misprints for Cilicia. This form has been discussed under the heading "Southwest Asia."

FIG. 12.—Heads of Holcus sorghum, L., and Holcus saccharatus, L., after Arduino, 1786.

About 1775 Arduino began at Padua, Italy, his experiments in sugar production from sorghums. He carried on this work for fully ten years, and in 1786 published a comprehensive paper in which he described six supposed botanical species of sorghum and gave full notes on their culture and uses. He seems to have been the first author who gathered together and grew for a number of years all the forms he could secure. Of the six varieties thus described as species, one was a new sweet sorghum from "Cafreria" (Natal), South Africa, one was the white durra of southwestern Asia, and the other four were forms long cultivated in Italy. The six species were all splendidly illustrated on folio plates, which are here repro-

duced as figures 12 to 15. They were all commonly used for human and animal food, and the older ones were also used in the making of brooms. After Arduino's work ceased, for causes not explained, no especial attention seems to have been given to sorghum for sirup or sugar production until the middle of the eighteenth century.

In 1851 a saccharine sorghum from China arrived in France. It had been sent with many other seeds to the Royal Geographical Society by M. Montigny, the consul at Shanghai. It was obtained from the island of Tsungming (Chungming), lying in the mouth of the the Yangtze River, in latitude 32° north. A single seed is said to have germinated in the garden at Toulon, where the seed was sent. The resulting crop was secured at a high price by Louis Vilmorin, of Vilmorin-Andrieux & Co., well-known seedsmen of Paris. This seed, sold widely in Europe and afterwards in the United States, was the foundation of the variety long known as Chinese sorgo (fig. 9).

FIG. 13.—Head of Holcus cafer, after Arduino, 1786.

In March, 1851, Mr. Leonard Wray, an English sugar planter, arrived in Natal, South Africa. Soon after, his attention was attracted to numerous varieties of sorgo called "imphee," which the Zulus or Kafirs cultivated for the sweet stems. These people knew nothing of the art of expressing the juice by mechanical means, but simply chewed the peeled stems. After considerable search Mr. Wray succeeded in getting together sixteen varieties under their native names. These he brought to Europe about 1854 and arranged to

have grown in various countries. From these varieties have descended most of the sorgos now grown in the United States.

With these two importations was inaugurated a long series of thorough and expensive experiments in making sugar and alcohol from sorghum, which continued without interruption for thirty years. During the progress of similar work in America, large quantities of the seed of our leading saccharine varieties were sent from here to Spain and other parts of southern Europe. Neither these nor Mr. Wray's original importations seem to have persisted there in cultivation as pure varieties.

FIG. 14.—Head of Holcus niger, after Arduino, 1786.

At the present time few varieties are to be found in Europe, and these are usually very badly mixed. A rather large, somewhat saccharine variety, with spikelets much as in Gooseneck sorgo, but with a compact, obovate, erect, black head, is found in Germany, France, and Austria. It is quite different from any variety now grown in the United States and is probably a remnant of the importation from Natal. Some Amber and Orange sorghum can still be found in France and Spain. It is probable that the blood of a number of the different saccharine varieties is mingled in the variable and often worthless hybrids now found in southern Europe.

A white durra is found in occasional cultivation in Europe. It is the form prevalent in northern Africa rather than that of Arabia and Syria, and has come largely from Algeria by way of France (fig. 6, *e*).

South America.

No sorghum varieties are indigenous to the New World. *Andropogon halepensis* itself is an introduction, though now found abundantly in tropical and subtropical America. In South America broom corn is quite widely but not extensively grown. Amber sorghum from the United States is sparingly introduced. No other varieties are found, except occasionally under trial at experiment stations.

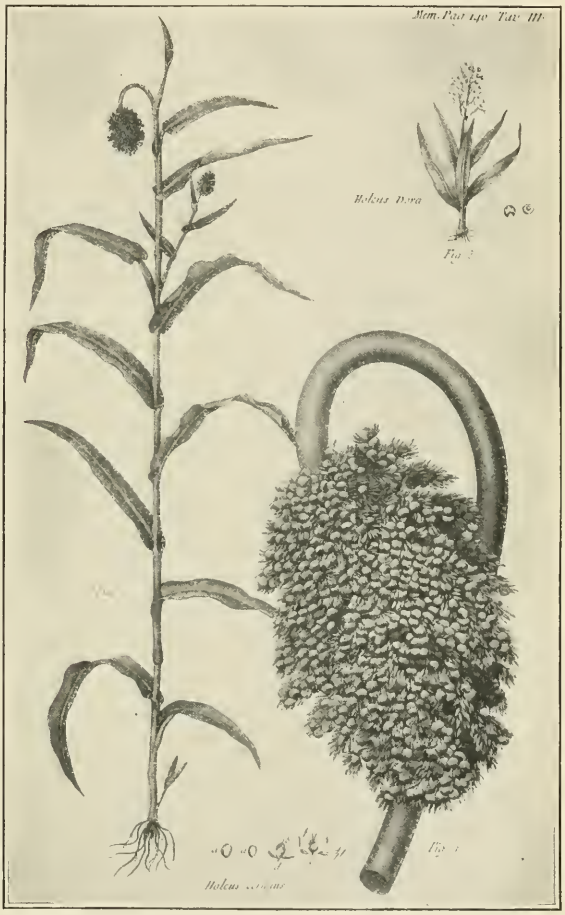

FIG. 15.—Plant and head of Holcus cernuus, after Arduino, 1786.

West Indies and Central America.

Throughout the West Indies and sparingly on the east coast of Central America a variety is found quite similar to blackhull kafir in the characters of the head. In its vigorous stooling and abundant leaves it still more closely resembles other African varieties. It was introduced long ago from the Guinea coast of Africa with the slaves, whose food it had been in their native home. Sloane records it as widely cultivated in Jamaica in 1707. In the English islands it was, and still is, known as "Guinea corn," in the French islands as "petit millet," and in Honduras as "maysillo" (probably "little corn"). It is quite generally cultivated for human food for

the laboring classes, and also as forage for stock. The small seeds are white or pearly white in color and the short glumes are usually black. It is probably the progenitor of the form occasionally found in the United States under the name "white millo maize," and for which the author has suggested the name Guinea kafir. It has no value in this country, unless perhaps for silage in the extreme South.

United States.

The early history of sorghum varieties in the United States is quite obscure. It is known that the growing of broom corn for domestic use became a considerable industry in colonial times. It is certain also that some grain varieties were introduced and sparingly grown in the early days of the colonies. From time to time a variety, though not always the same one, was exploited, under the name of "chocolate corn," as a substitute for tea and coffee. However, aside from broom corn, no sorghum had become a permanent crop before the middle of the last century.

Accounts vary somewhat as to the date and manner of the first introduction of the Chinese sorgo (fig. 9) from France. Apparently it was first grown by William R. Prince,[a] a nurseryman, of Flushing, Long Island, New York, in 1853, and sold by him to a few other persons for testing in 1854. A hogshead of seed was sold by him in 1855. The United States Commissioner of Patents[b] secured a small quantity of the seed in France in 1854 and grew it in 1855, continuing the experiment through the succeeding year. In that year, 1856, a 75-foot row was grown by the editor of the American Agriculturist[c] from seed secured from the firm of Vilmorin-Andrieux & Co., of France. In the spring of 1857 the American Agriculturist distributed over 1,600 pounds of the seed to 31,000 of its subscribers. Most of the seed was imported direct from France, though a small quantity was secured from growers in the vicinity of New York, N. Y. In the same year the United States Patent Office distributed 175 bushels of home-grown seed and 100 bushels of imported seed. In the spring of 1858 the American Agriculturist distributed, in 1-pound packages, 34,500 pounds of seed grown in Georgia from its imported seed of the year before. It is not probable that extensive distributions were made after this date. The supply already sent out was sufficient to scatter the variety very extensively over the entire country. The widespread and increasing interest in this crop was

[a] Report, U. S. Dept. of Agriculture, 1877, p. 233.

[b] Reports, U. S. Patent Office, 1854, pp. xxii and 219–223; 1855, p. xii and 279–280; 1856, p. 5. Report, Iowa State Agricultural Society, 1861, p. 207.

[c] American Agriculturist, vol. 20, 1861, p. 6; vol. 39, March, 1880, p. 116; vol. 40, March, 1881, p. 94.

not because of its forage, or even its sirup value, but as a probable source of sugar. It was then known as sorgho in Europe and America.

In May, 1857,[a] the sixteen saccharine varieties obtained by Mr. Leonard Wray in Natal in 1851 were brought by him from Europe to the United States at the request of Hon. Horace Greeley. They were not distributed to the public, but were first sown in South Carolina and Georgia under Mr. Wray's immediate supervision. He had taken out United States patents on his method of making sirup and sugar, and is said to have purposed controlling the income from the use of his varieties. These African varieties were known collectively as "imphee," each variety having in addition a native Zulu name. The names of the varieties, as published by Olcott (1857), were as follows: Vimbischuapa, Eanamoodee, E-engha, Neeazana, Boomvwana, Oomseeana, Shlagoova, Shlagoondee, and Zimmoomana, with brief descriptions, and Ebothla, Booeeana, Koombana, See-engla, Zimbazana, and Ethlosa, mentioned by name only. In the pronunciation of these names each vowel, except where doubled, is the basis of a syllable. Though only fifteen names appear, Mr. Wray states that sixteen varieties were obtained by him in Natal. Many years later Wray[b] identified plate 5 in Special Report No. 33 of the Department of Agriculture and in the report of this Department for 1880 as his "Enyama," which is not given in the list above, but was doubtless the sixteenth variety. A variety was on sale in the city of New York under this name in the spring of 1859.

Between the years 1860 and 1880 agents were sent to China[c] to discover and bring back other varieties, and considerable importations were made also from South Africa and India.[c] No other saccharine varieties were found in China, though several ordinary kowliangs were obtained. The importations from Africa, though coming under names very different from those of Mr. Wray's forms, apparently did not represent any new varieties. The Indian varieties were either nonsaccharine or so slightly saccharine as to be valueless for sirup or sugar production. They were mostly too late to be of much value for forage and grain.

All these varieties were soon as widely distributed over the country as their particular climatic adaptations would permit. Hybridization, variation, and selection, combined with the desire of growers to

[a] Hedges, I. A. Rural New Yorker, vol. 40, May 7, 1881, p. 1. American Agriculturist, vol. 16, 1857, pp. 142, 276–277.

[b] See Collier, 1884, p. 68.

[c] Sorgo Journal, vol. 7, October, 1869, p. 91; Collier, 1884, loc. cit., pp. 76–82; American Agriculturist, vol. 45, April, 1886, pp. 153–154; Bulletin 20, Bureau of Chemistry, U. S. Dept. of Agriculture, 1889, pp. 112, 119.

find a market for their seed, resulted in the speedy multiplication of the so-called "varieties" to an enormous extent. Two hundred or more names are recorded for saccharine varieties alone. It is doubtful if the number of actual varieties concerned was ever more than twenty. Not more than a dozen are now in cultivation in this country. Of these, Amber and its forms are said to be directly derived from the original Chinese sorgo, though it has not been proved that some of these forms were not secured in Africa. All others are presumably descended from the Natal varieties. The definite varietal origin of some is known, as Orange and perhaps Planter from Neeazana, and Sumac from Koombana; others, as Collier, Planter, Sapling, Gooseneck, Honey, etc., can not be certainly connected with a particular one of the poorly described African varieties, but are most surely original sorts from that source.

The sorgos, or saccharine sorghums, are now grown to a very limited extent for sirup production and to quite a large extent for forage. The total area grown in the United States is probably about one and one-half millions of acres annually. A large part of this is in the southern half of the Great Plains area. During the recent unusually wet seasons there has been a perceptible decrease in the acreage in that region, owing to the opportunity for better crops of corn and cereals. The Amber, Orange, and Sumac varieties make up the bulk of the crop.

Kafir and durra are of quite recent introduction and distribution in the United States. Varieties of the kafir group first reached this country in 1876, but were not generally distributed until ten years or more later. The original variety, white kafir, has almost completely disappeared from cultivation. Its place has been taken by the more recent blackhull kafir, which makes up probably nine-tenths of the total kafir crop, red kafir furnishing the remaining tenth. White durra and probably other durras have been introduced many times since colonial days, but without permanent results until 1874, when our white durra and brown durra were brought into California. The total area of these two crops probably does not exceed 50,000 to 60,000 acres annually. Milo appeared about 1885 under circumstances not yet ascertained. The annual acreage is probably about 300,000 acres. The total area devoted to kafirs and durras combined is probably not far from another one and one-half millions of acres. This would make a grand total of three million acres of sorghums annually grown in the United States.[a] Their annual value may be conservatively estimated at $30,000,000.

[a] These estimates were made in June, 1908.

Canada.

The earliest maturing varieties of sorgo from the United States, chiefly Amber and its forms, have been grown in Lower Canada for some years as hay and fodder crops.

BOTANICAL HISTORY AND NOMENCLATURE OF SORGHUM.

PRE-LINNEAN PERIOD, FIRST CENTURY TO THE YEAR 1753.

During the early part of the pre-Linnean period sorghum was introduced into Europe and became widely cultivated under many popular names. With the revival of learning in the latter part of the period it received abundant attention in agricultural and medico-botanical literature and acquired a considerable polynomial nomenclature.

According to Pliny, as has been stated, sorghum was introduced into Italy from India during the first century. In his writings he includes it under the general term "milium," or millet, used then, as now, to designate the cultivated forms of several different species of grain-producing grasses. The most important of these were the grasses now known as *Panicum miliaceum* (proso millet) and *Chaetochloa* (*Setaria*) *italica* (foxtail millet). Pearl millet (*Pennisetum spicatum*) and even corn (*Zea mays*) were included under the name milium by various ancient authors.

Even from the very brief description given by Pliny we may be sure that he was writing of some sorghum. "Milium intra hos decem annos ex India in Italiam invectum est, nigrum colore, amplum grano, harundineum culmo, adolescit ad pedes altitudine septem prægrandibus culmis: lobas vocant: omnium frugum fertilissimum. Ex uno grano terni sextarii gignuntur. Seri debet in humidis. Frumenta quædam in tertio geniculo spicam incipiunt concipere, quædam in quarto, sed etiam num occultam." The very stout, reed-like culms, 7 feet tall, exclude all other millets except pearl millet. The abundant grain and black color separate it from that species, while all these characters agree readily with those of sorghum.

Origin of Popular Names.

The name milium is derived from miliarius, or milliarius, which means "containing a thousand," and has reference to the large number of seeds in each head. From it our words millet, millo, and milo have been derived. For many centuries sorghum in general was known as milium, or milium indicum, literally Indian millet, and this latter name was still in use fifty years ago. Just how early other names came into use for sorghum can never be known, owing to the lack of literature on such subjects during mediæval times. It is natural that such names should have originated soon after the intro-

duction of this crop and should have increased in number as the plant became more widely distributed among tribes and nations.

By the beginning of the sixteenth century sorghum was to be found throughout Italy, Spain, France, Belgium, and Germany under a great variety of names. A very large number of these names were used in different parts of Italy. Melica, melega, and milica were derived from either "mel" or "mellis" (honey), or more probably from "melligo" (a honey-like juice). Sagina, or saggina, was derived from the Latin "sagino," to fatten. Sorghi, sorgi, sorgho, sorgo, sorghum, and surga are derivatives from the Latin "surgo," to rise or tower, in reference to its towering high above all other crops. In Germany there was applied to it the distinctive name "Welschenhirse," i. e., foreign, or, more particularly, Italian millet, and also "Sorgsamen." In Belgium the name "sorgsaet" was given it. The derivation of these last names from the Italian "sorgho" is obvious. It was known also as *Milium indicum*, *M. insubrum*, *M. sabaeum*, and *M. saracenicum*, as the seed was thought by the various writers to be of Indian, North Italian, Arabian, or Saracenian origin, respectively.

Throughout the past century all writers on sorghum in cyclopedias and agricultural and botanical works have reiterated that the name sorghum, or sorghi, is the common name of this plant in the Orient. There is not the slightest evidence in support of the theory; on the contrary, as early as 1592 Porta had pointed out its origin from the Latin "surgo."

Early Authors and Early Names.

It is impossible to take up in detail the statements made by the many medical and agricultural writers of the sixteenth century and earlier. The latter repeated the facts and also the errors of the earlier authors, with additional notes of their own. The following is a chronological list of the more important pre-Linnean authors, showing the names under which they discuss sorghum. In most cases they also cite other names by which sorghum was known among the different nations of their time:

Pliny, first century, "Milium ex India."
Ruel, 1537, "Mellica."
Crescenzi, 1542, "Saggina," "Melica."
Fuchs, 1542, "Sorgho."
Tragus (Bock), 1552, "Panicum."
Scaliger, 1556, "Sorghum."
L'Obel, 1576, "Sorgho," "Melica Italorum."
Dodoens, 1583, "Melica" or "sorghum."
Cæsalpini, 1583," "Melica," "Sagina."
Porta, 1592, "Sagina," "Melica," or "Surgo."
Mattioli, 1598, "Milium Indicum."
Belon, 1605, "Sorghum Insubrum."

Besler, 1613, "Milium Plinii;" "Sorghum fructo rubro;" "Sorghum fructo albo."

Bauhin, C., 1623, "Milium Sabaeum;" "Milium arundinaceum subrotundo semine, Sorgo nominatum;" "Milium arundinaceum plano alboque semine."

Parkinson, 1640, "Melica, sive sorghum."

Bauhin, C., 1658, "Milium arundinaceum sive Indicum semine subrotundo;" "Milium arundinaceum semine plano et albo."

Hermann, 1687, "Milium indicum, arundinaceo cauli, granis flavescentibus;" "Milium indicum, arundinaceo cauli, granis nigris;" "Milium arundinaceum subrotundo semine; Sorgo nominatum;" "Milium arundinaceum plano alboque semine."

Ray, 1688, "Sorghum" or "Milium Indicum;" "Milium arundinaceum semine subrotundo;" "Milium arundinaceum semine plano et albo."

Breyne, 1689, "Milium Indicum sacchariferum altissimum semine rotundo atro;" "Milium Indicum sacchariferum altissimum semine ferrugineo."

Sloane, 1696, "Milium Indicum."

Morison, 1699, "Milium majus Sabaeum;" "Milium majus arundinaceum subrotundo semine;" "Milium majus arundinaceum plano alboque."

Tournefort, 1700, "Milium arundinaceum."

Sloane, 1707, "Milium Indicum."

Micheli, 1729, "Sorgum" (nomen nudum).

Linné, 1737, "Holcus glumis glabris;" "Holcus glumis villosis."

Just what variety of sorghum was introduced into Italy in Pliny's time we have no means of knowing. There is at least a strong probability, however, that it was a sweet variety. Pliny describes the seed or head as of a black color, apparently not distinguishing between the seeds and the black glumes which inclosed them. In recent times most black-glumed forms with seeds wholly inclosed have been saccharine varieties. At any rate, a sweet variety must have been introduced at an early date, because we find such names as melica and melega, referring to sweetness, in use as early as any names more distinctive than milium or panicum. Between the first and sixteenth centuries there is naturally not a very extensive literature on the subject. Avicenna, who lived in the tenth century, writes of a form used by the Arabs and called "hareoman" (said to be a misprint for hartoman). Crescenzi (1542) is said to have written about 1300 A. D., and later editions of his work refer to the plant in Italy as sagina, or melica. The writer has been able to consult no edition earlier than the one cited.

SIXTEENTH CENTURY WRITERS.

During the sixteenth century many able writers describe the plant and its uses; some give good illustrations. None of them recognizes more than a single variety.

Fuchs (1542) and Tragus (1552) figure similar plants with heavy and compact but erect heads (fig. 10). This sorghum is much like the Orange sorgo in general appearance and is apparently the variety afterwards named *Holcus sorghum* by Linné. It is certainly the

plant so recognized by Arduino (1786). L'Obel (1576) figures a variety with more open panicles, like the early illustrations of the Chinese sweet sorghum. Dodoens (1583) and Parkinson (1640) use the same figure (fig. 11). Mattioli (1598) shows a different form (fig. 16), somewhat intermediate in head characters between the other two.

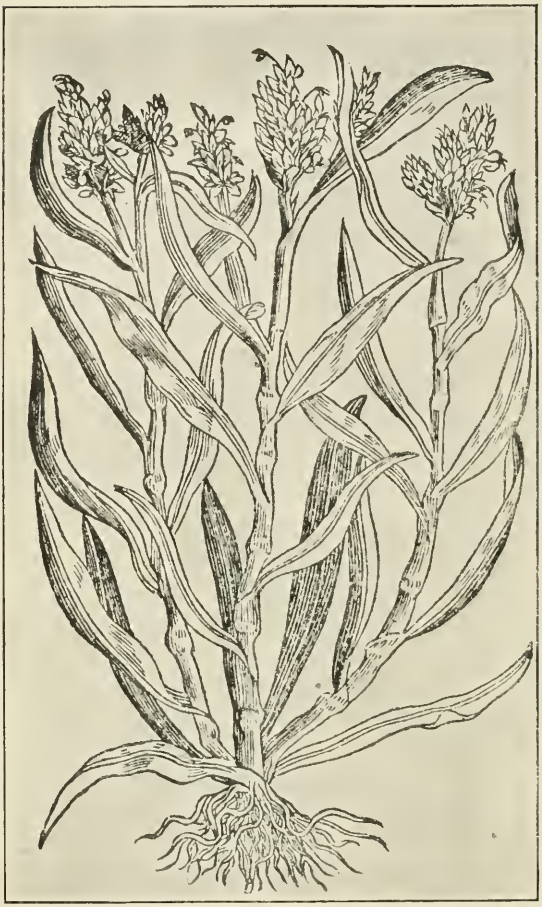

FIG. 16.—Plant of sorghum, after Mattioli, 1598.

Tragus (1552) speaks of the sweet fodder produced by sorghum. Many other writers speak of the sweet seed, but the word sweet, as used by them, seems to refer to the absence of an astringent or bitter quality rather than to the presence of any saccharine character, which would of course not appear in the seeds. None of these writers makes direct reference to a sweet juice contained in the stems or to the use of the plant as a source of saccharine matter, unless indeed the following much-quoted words of the poet Lucian, who wrote presumably in the second century A. D., "Quique bibunt tenera dulces ab arundine succos," may be construed as referring to sorghum. Except in describing the stalks as tender, this description applies equally well to sugar cane, and it may be only a bit of poetic license.

Those who describe the plant speak of the seeds as red or reddish. Some authors mention forms with seeds of various colors, from white to black. Cæsalpini (1583) states, however, that only the form with purple spikelets is the plant commonly called sagina, or melica, the others being the smaller millets.

SEVENTEENTH CENTURY WRITERS.

The writers of the seventeenth century began to separate the plant into varieties or races, based chiefly on the color of the seeds. Bauhin (1623), under the general heading "Milium Eiusque Species," names, with copious synonymy and brief description, five different kinds, the first two of which, "*Milium semine luteo vel albo*" and "*Milium semine nigro*," are probably not sorghums. The last three, however, "*Milium sabæum*," "*Milium arundinaceum subrotundo semine, Sorgo nominatum*," and "*Milium arundinaceum plano alboque semine, Sorgo simile granum, Hareomen Arabum*, Bellonio," are almost certainly different varieties of sorghum. The first of these three is not described, but as the name is derived from Saba, the capital city of Sabæa, in Arabia, the plant may have been the same as the third form. The second is the form which was then commonly grown in southern Europe and which had been described and figured by many earlier writers. The third, from the description and synonymy, is clearly the white-seeded durra of Arabia mentioned by Avicenna, Rauwolf, and others. Two distinct varieties are here discussed, the common European form with reddish seeds and an Arabian variety with white seeds, the latter probably a form of white durra.

Parkinson (1640) describes sorghum under the title "Melica sive sorghum, Indian Millet." He uses the same figure as several other authors, namely, that of L'Obel. Evidently only one variety is in his thought and that one the common and long-cultivated form. Of the white, flat-seeded variety he makes no mention.

Caspar Bauhin (1658) gives full descriptions of the two sorghums he had merely listed under *Milium arundinaceum* in his "Pinax" (1623). These were the common sorghum of Europe and the white-seeded sorghum of Arabia. The common form he describes as producing from one seed 4 to 5, or more, stout and somewhat sweet culms, with leaves 1½ feet long and 3 to 4 inches wide, and erect heads 9 inches long and 4 to 5 inches in width, containing abundant seeds, mostly reddish or deep red, occasionally pale or yellowish in color. This sorghum had been introduced from India into Spain, Italy, and elsewhere. Bauhin thus holds the sorghum of Europe to be but a single variety or species, the milium indicum of Pliny. His figure is that of Mattioli, sixty years before. The white-seeded form of Arabia, Mesopotamia, and Asia Minor he notes as having a culm similar to corn or sugar cane, 9 to 12 feet high, filled with sweet pith, from which the natives extract, by chewing, a sweet juice, and bearing a beautiful white panicle 6 inches long, containing hard and brilliantly white, flattened seeds. From the white durra now grown extensively in the same region this form apparently differs in two important respects—the sweet juice and the erect heads. Bauhin

does not state that the heads are erect, but so striking and unusual a character as pendent heads would certainly have received mention if known to him. It is, however, quite possible that this fact had not become known in Europe, since the plant was cultivated no nearer than Cilicia in Asia Minor. If it is, indeed, the progenitor of the white durra now occupying the same region, the saccharine quality of the juice has been entirely lost.

Hermann (1687) presents the different forms of sorghum in the following manner:

Milium indicum, arundinaceo cauli, granis flavescentibus.
Milium indicum, arundinaceo cauli, granis nigris.
Milium arundinaceum, subrotundo semine, Sorgo nominatum.
Milium arundinaceum, plano alboque semine.

The first two he evidently thought to be new and so described them. The last two are simply quoted on the authority of Bauhin, without description. Hermann seems to think his second variety to be the Indian sorghum of Pliny. He describes it as having black seeds, but does not mention the glumes, while in the first form he speaks of the seeds as pale and the glumes as black and brilliant. Since there are no sorghums with black seeds (grana nigra lucida) it is probable that his two varieties were the same thing, described from hearsay rather than observation. In the first variety the color of the actual seed is given; in the other, the color of the spikelet.

Ray (1688) cites the two varieties of C. Bauhin, omitting *Milium sabaeum*, and copies most of Bauhin's notes on them.

Breyne (1689) discusses sorghum as "Milium Indicum sacchariferum altissimum," and describes two forms having "semine rotundo atro" and "semine ferrugineo," respectively. He is the first author to recognize the saccharine content of the plant in forming a name for it. This work is not accessible, and it is not known what varieties Breyne had in hand.

Sloane, in his "Catalogus" (1696), gives a copious bibliography and synonymy of this plant, including all previous authors.

Morison (1699) places under the generic heading Milium two subgroups: Minus, including wild and cultivated species of Panicum, and majus, including sorghums and probably pearl millet. Of sorghums there are three, the names being quoted from C. Bauhin and identical with those used by him in his "Pinax" (1623). Concerning the white-seeded variety he gives the new and important information that the head is pendent, but has no illustration of it. In his description of *Milium sabaeum* no mention is made of a pendent head, but his figure shows a group of two stalks, one bearing an erect head and the other a pendent head. Both varieties were Arabian, and it is quite possible that they were the same. He is the first author who definitely records a sorghum with a pendent head.

EIGHTEENTH CENTURY WRITERS.

Sloane (1707) gives a description of the Guinea corn of Jamaica. In this connection he supplements the synonymy given in his earlier "Catalogus" by citations from subsequent authors. He states that this form of sorghum was then in very general culture on that island, as it probably was in others of the West Indies. From the brief description, the plant seems to be identical with the variety peculiar to and extensively grown in many of the West Indian islands at the present day under the same name, Guinea corn. It is almost certain that this plant was brought from the west or Guinea coast of Africa with some of the slaves, whose chief food-grain it had been in their African home. It is discussed in this bulletin under the name Guinea kafir (fig. 3, *b*) in the paragraph on the West Indies.

Micheli (1729) proposed the generic name Sorgum for these plants as segregates from the genus Milium of Tournefort. He did not, however, describe any species in this connection, nor did he indicate what plants of Tournefort should be included in his genus. The name stands, therefore, as a nomen nudum. Tournefort in 1700 had simply lumped sorghum with *Panicum miliaceum* as milium, and cited under it all the names given by the two Bauhins with some new ones of his own, which are, however, not worthy of further attention.

Linné (1737) transferred these plants to his recently erected genus Holcus. The common form is treated as *Holcus glumis glabris* and the white-seeded, or durra, variety from Arabia as *Holcus glumis villosis*. For our purposes this work terminates what is called the pre-Linnean period, the next botanical contribution of any great importance being Linné's "Species Plantarum," wherein began in 1753 the general application of a binomial system of nomenclature for plants.

LINNEAN PERIOD, 1753 TO 1850.

Throughout the Linnean period botanists treated the diverse forms of this cultivated plant as botanical species. Nearly thirty species were named and about sixty binomial combinations made.

THE SPECIES OF LINNÉ AND FORSKÅL.

Linné (1753) published two species of sorghum under his exceedingly composite genus Holcus, namely, *Holcus sorghum* and *H. saccharatus*, adding thereto the wild species as *H. halepensis*. The cultivated species were both from India. Under *Holcus sorghum*, described as "glumis villosis seminibus aristatis," he evidently placed the common European sorghum of earlier authors, since he makes his *Holcus glumis glabris* of 1737 a synonym. The Arabian form with flat white seeds is not mentioned at all, either by name or in the synonymy, though by inference it is included in this species. *Holcus*

saccharatus is described as "glumis glabris seminibus muticis," based on the *Milium indicum granis flavescentibus* of Hermann and the *Milium indicum sacchariferum altissimum seminibus ferrugineo* of Breyne. In the second edition, 1763, it is described as having an erect, subverticillate panicle with wide-spreading or somewhat drooping branches, in contrast with the small, erect, and ovate heads of *Holcus sorghum*. Both species are credited with villous glumes and awned lemmas (flowering glumes), and are distinguished by the size and character of the panicle.

In his "Mantissa" (1771) he restricts the name *Holcus sorghum* to a strain of the ovate-panicled form with green villous glumes, and adds Bauhin's form with flat white seeds as a synonym. He then permits the open-panicled *Holcus saccharatus* to have hairy glumes and awned lemmas also, and describes a new species, *Holcus bicolor*, similar to *H. sorghum*, with glabrous black glumes and globose white seeds, in awned lemmas, transferring his *Holcus glumis glabris* of 1737 to *Holcus bicolor* as a synonym. This new species was said to have come from Persia, which probably indicates that it was an Indian variety perhaps secured through Persia. A similar form is found abundantly in India to-day. It could scarcely have been the white durra of Arabia, etc., because that had pale glumes.

Forskål (1775) added two species from Egypt: *Holcus dochna* and *H. durra*, the specific names being derived from the common names of the varieties in that country. *Holcus dochna* was probably a saccharine or semisaccharine sort, but is not now certainly identifiable. Both Koernicke (1885, p. 310) and Hackel (1889, p. 509) place it as a synonym under *saccharatus*. Forskål does not mention it as saccharine, but the description accords well with that of the sweet forms. His *Holcus durra* included at least two of the three durra varieties common in Egypt to-day, namely, the white seeded (beda) and the brown seeded (ahmar). Indeed, Forskål makes it cover two white-seeded forms, one with greenish glumes and one with brownish glumes. Koernicke (1885, p. 312) places the reddish-brown-seeded sort under the variety *arduini* Gmel. In 1887 he proposed the name *egyptiacus* for the white-seeded form. Hackel follows him in this, placing under his variety *durra* only a yellow-seeded (safra) form; he does not seem to have had the brown-seeded form at all. These three forms, beda, safra, and ahmar, with white, yellow, and brown seeds, respectively, are in common cultivation in Egypt to-day. They are practically identical except for the color of the seed, and really represent but a single botanical variety instead of three.

The Species of Arduino.

Arduino (1786) published descriptions of six species of sorghum, three of which he considered new, the other three being those de-

scribed by Linné. All the species are excellently illustrated on folio plates, and the descriptions are more exact and complete than those of any previous author. Arduino's paper had been presented in 1780 and his experiments had been in progress since 1775, and perhaps for a longer period. He was probably the first author to grow and carefully study in the field all the forms he could obtain. His three new species are *Holcus cafer*, *H. cernuus*, and *H. niger*.

His *Holcus cafer* is the most interesting of all, because it was a recent arrival in Italy from "Cafreria" (Natal), in South Africa, which Arduino describes as "an exceedingly vast province of Africa." How it was obtained is not stated. The description and figure show a form with an umbellate panicle, the long, heavily seeded branches drooping in the form of an umbrella (fig. 13). In appearance it is identical with the drooping strain of Planter sorgo now grown in this country, and which is of known Natal origin. We thus have our Planter sorgo antedated by seventy-five years. Arduino's variety was described as 8 feet or more in height, with stalks as large as American corn, 12 or 13 leaves, and an umbrella-like panicle with drooping branches 6 inches long. The heavy stalks, filled with sweet juice, weighed three or four times as much as those of the ordinary forms, and the stems and foliage remained green until frost, even when the heads were harvested. The reddish seeds were considerably exserted from the small hairy glumes. It is the *Sorghum arduini* of Jacquin (Eclog. Gram., pl. 18, 1791); the variety *cafer* of Koernicke (1885, vol. 1, p. 307); and is doubtfully admitted by Hackel (1889, p. 519).

Arduino believed his *Holcus niger* to be the black sorghum of Pliny and Tournefort. He illustrates (fig. 14) a loose, ovate-pyramidal panicle not nearly so lax and spreading as that of *Holcus saccharatus*. It is much like some of our more compacted Amber forms and the Oomseeana of Wray.

Arduino's *Holcus cernuus* (fig. 15) is our white durra, based on the white-seeded variety of Arabia, etc., discussed by so many of the older authors. Arduino is naturally puzzled by the action of Linné in uniting this form with his *Holcus sorghum*, as he did in his "Mantissa" (1771).

In Arduino's interpretation of Linné's *Holcus sorghum* (fig. 12), it is described as from 6 to 8 feet in height and an inch in diameter, with 8 to 10 leaves and an erect, oval, compact panicle full of seeds of various shades of red and yellow, some included and some partly exserted, the lemmas being awned or awnless. Linné's *Holcus saccharatus* (fig. 12) Arduino describes as a tall, slender cane with long, slender leaves and a sparse, lax panicle about a foot long, with drooping branches, awned or awnless spikelets, smooth or hairy glumes, and

seed varying from pale yellow to deep red. He states that these three species, *Holcus sorghum*, *H. niger*, and *H. saccharatus*, had long been cultivated in Italy and were very variable. He calls them light yielders of seed. From *Holcus sorghum* floor brooms were made, and from *Holcus saccharatus* all kinds, from whisk brooms to scrubbing brushes. He calls especial attention to the variability of the species *Holcus sorghum* and *H. saccharatus*. While it is likely that other importations than that recorded by Pliny were represented in the forms described by Arduino, it is certain that many of these forms must have arisen through variations and crossing which took place in Europe. For many years thereafter these varying forms were made the basis of new species by the botanists of that period.

Numerous Species of Later Authors.

Koeler (1802) founded his genus Blumenbachia on the wild *Holcus halepensis*, but the name was never taken up for the cultivated plant. Brotero (1804) transferred *Holcus sorghum* and *H. halepensis* to the genus Andropogon. Persoon (1805) took up the old generic name Sorghum, first proposed by Micheli, and rechristened the cultivated plant *Sorghum vulgare*. During the first half of the nineteenth century many more cultivated forms were described as new species, until the total number of species was thirty or more. The following is an alphabetical list of the names used for cultivated sorghums described as species: *Albus*, *arduini*, *besseri*, *bicolor*, *cafer*, *caffrorum*, *campanum*, *cernuum*, *commune*, *compactus*, *dochna*, *dora*, *drummondii*, *duna*, *durra*, *dulcis*, *ferrugineus*, *nervosum*, *nigricans*, *niger*, *nigerrimus*, *pyramidale*, *rubens*, *saccharatus*, *sorghum*, *subglabrescens*, *truchmenorum*, *usorum*, *versicolor*, and *vulgare*. Some of these names have been used in all three genera, Holcus, Sorghum, and Andropogon; some have been used in two; others only in one. In this manner a total of fifty-five or sixty binomial combinations has been reached.

Most of these so-called species are quite unimportant. A few of them probably include forms which have since become extensively cultivated in this country. It is almost impossible to identify these species from their meager descriptions, especially those described from regions where sorghums are abundant and variable. In consulting the writings of different authors who discuss a form under the same specific name, it becomes evident that they did not always have the same plant in hand. For example, the name *bicolor* of Linné has at one time or another been applied to almost every form with white seeds and dark glumes. In the same way the name *cernuus* of Arduino has been used for all forms with pendent panicles, without much regard to other characters involved.

RECENT PERIOD, 1850 TO THE PRESENT TIME.

By the middle of the last century the conception of cultivated forms of sorghum as species had been abandoned and the description of them as horticultural and botanical varieties was begun. Olcott (1857) published Leonard Wray's brief descriptions of his recently introduced Natal varieties (fig. 17). Stewart (1867) reprinted these descriptions, but neither attempted any classification.

BEGINNINGS OF CLASSIFICATION.

Pech (1865) published a provisional classification of the few sweet varieties then known to him. Collier (1884) amplified Pech's out-

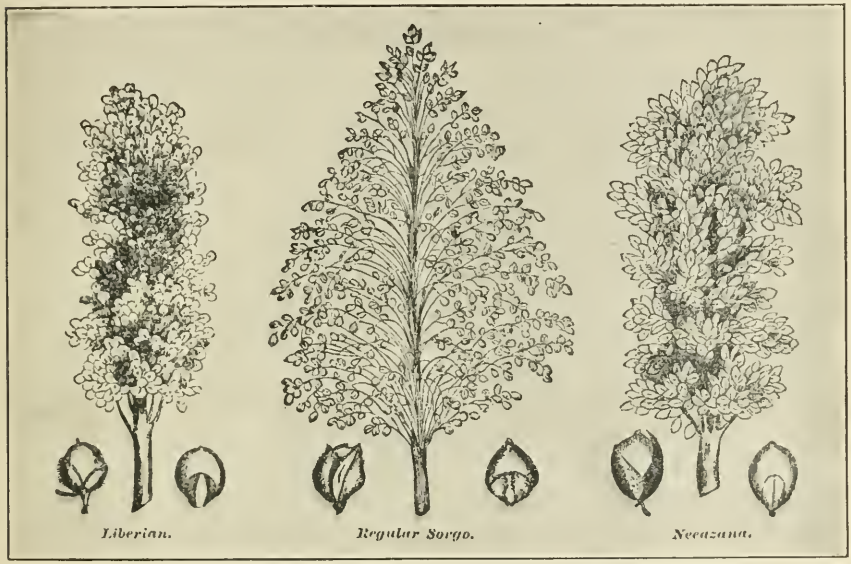

FIG. 17.—Heads of three sorghum varieties figured in 1869. "Liberian" is Wray's Koombana, the present Sumac; "Regular sorgo" is the Chinese variety; and "Neeazana" is the original form of Orange.

line by inserting a number of recently developed saccharine varieties, many of which were local strains that never became generally grown and are not now identifiable. These two classifications were made on a natural basis, and if fuller and more definite would be fairly usable, though wrought out from confessedly imperfect material and insufficient field study and including only a limited number of forms, of which all except one were sorgos.

Koernicke (1885) presented the first attempted classification of the cultivated forms of the whole world. He recognizes them as comprising a single species *Andropogon sorghum* (L.) Brot., and disposes them in twelve varieties, grouped into two sections, Effusus and Contractus, referring to the habit of the panicle.

The first section includes five varieties: *Cafer* Ard., *technicus* Kcke., *saccharatus* L., *leucospermus* Kcke., and *niger* Ard. The first two varieties are separated from the others by having a much shortened rhachis, or central axis, in the panicle. The variety *cafer* is our Planter sorgo, or a very similar variety, while the variety *technicus* is broom corn. The last three are apparently all sorgos or sweet sorghums. The variety *saccharatus* is much like our most spreading Red Amber, the variety *leucospermus* is not determinable, and the variety *niger* is probably identical with some of our smaller and more compact Amber forms, as Black Dwarf. Koernicke's *leucospermus* had not white seeds, but red, the inappropriate name apparently referring to the pale glumes, due perhaps to the acknowledged late and incomplete maturity of the specimens on which it was based.

The second section contains seven varieties, of which the first four—*usorum* Nees., *arduini* Gmel., *aethiops* Kcke., and *bicolor* L.—had erect heads, and the last three—*cernuus* Ard., *truchmenorum* Koch., and *neesii* Kcke.—had the heads pendent. Of the first group, with erect panicles, the variety *usorum*, with short compact heads, is not certainly identifiable with any of the hundred or more Natal forms studied by the writer. Variety *arduini* is probably our Orange sorgo, variety *aethiops* is not known, though it is perhaps the sorgo form with ovate black heads still grown in central Europe. Variety *bicolor* is not identifiable among the many similar forms of India and equatorial Africa. Considering, now, the three varieties having pendent heads, it is known that the variety *cernuus* includes, among others, our white durra, and that the variety *truchmenorum* is that form of white durra with taller stalks and more compact heads found in Turkestan, where it is called, in Russian, "Dzhugara." Variety *neesii* is a blackhulled white durra from the region of Natal. It has never been found in the recent importations from there.

Hackel (1889) divides *Andropogon sorghum* into two subspecies, *halepensis* and *sativus*, thus including both the wild and the cultivated forms in a single species. His subspecies *sativus* is the *Andropogon sorghum* of Koernicke's classification and the *Sorghum vulgare* of Persoon. He divides this subspecies into nine sections, which contain a total of thirty-six varieties. These nine sections, or groups, are separated largely on such characters as the comparative shape and size of the spikelets, the comparative length and width of the glumes, and the relation of these to the seed. The density of the panicle, the position of its branches, the color of the seeds, and the presence and length of the awn are used as minor determining characters. No mention is made of the size and height of the culms, the character of the juice, the number or size of the leaves, the comparative length of the sheaths and internodes, or of the purpose for which the varieties are grown.

In Africa there naturally has been but little done toward a study of the numberless forms of sorghum. In Egypt the British agricultural officials have studied quite carefully the native varieties, and the writer is much indebted to them for various shipments of seed and for provisional classifications, which are apparently very accurate. Colonial officers in French West Africa [a] (Niger Valley and Senegal) and in German East Africa [a] have published brief notes on the leading varieties of their regions. Schumann (1895), Busse and Pilger (1902), and Pilger (1904) have described botanically a very large number of forms from German East Africa and from Togo on the Guinea coast. Their descriptions are apparently based on dried material, mostly heads. Without the cultivation and field study of varieties for at least two or three seasons, such descriptions are of little value to the agronomist.

In India a comprehensive effort to assort, classify, and describe the manifold forms of that extensive region is now being made. Hooker (1897) gives a synopsis of the varieties of India as outlined by Hackel and also by Stapf. The Reporter on Economic Products for India, Mr. I. H. Burkill, has been engaged for several years in this work. A synopsis of a portion of his outline of classification was published by Benson and Subba Rao (1906) with valuable additions of their own. For the varieties of the Madras Presidency, occupying the southern portion of the peninsula, these last-named gentlemen have made a provisional classification, which has the decided merit of taking into account the agronomic characters of the plants.

In recent years the number of trinomials and other polynomials applied to sorghum varieties has been increased to literally hundreds. It is an open question whether any useful purpose is subserved by the wholesale application of Latin trinomials to the exotic cultivated forms of a variable plant like sorghum, especially where the study is limited to immature or fragmentary dried material. Where a field study of the growing plants is also made, the final number of varieties is always greatly reduced and the practice becomes less objectionable.

A satisfactory classification of the varieties of sorghum or of any other cultivated plant must take account of the habit and characters of the entire plant, not merely of the panicles. The height, size, and color of the stalks, the comparative length of the internodes and sheaths, the number, size, and color of the leaves, the length, stoutness, and exsertion of the peduncle, and the number of branches and suckers are all of vital importance in the study of varieties. Comparative earliness, disease resistance, drought resistance, and pro-

[a] Dumas, 1905, and Lambrecht, 1903.

ductiveness, with other available ecologic characters, ought to be included.

Furthermore, the use of purely artificial keys must be given up and natural groupings substituted before much permanent good can come from any classification of cultivated varieties. The lumping of all the forms which happen to have white seeds or spreading branches or pendent panicles only adds to present confusion. It is necessary first to define the major natural groups which agronomic and botanic studies have shown to exist, even if such groups can not always be sharply separated by a single character. When this has been done the varieties in each group should be distinguished by the most obvious natural characters. In this way only can we hope to prepare the usable and instructive systems of classification so much needed for the varieties of all our widely disseminated and variable cultivated crops.

SUMMARY.

AGRICULTURAL HISTORY AND DISTRIBUTION.

All cultivated sorghums are held to have been derived from the wild species *Andropogon halepensis*.

Many facts point to an independent origin in tropical Africa and in India, which are the two great centers of sorghum production, each occupied by an enormous number of varieties.

Sorghums, as crops cultivated for human food, date from the most remote historic times.

In varying forms sorghum is found abundantly throughout Africa and across the southern half of Asia. It is less abundantly distributed in southern Europe and in the United States and the West Indies.

Sorghum varieties furnish the chief cereal food of the native millions in Africa.

In British South Africa kafirs and sorgos are the predominating groups, represented by numerous varieties. Most of the kafirs and sorgos cultivated in the United States were obtained in this region, which is similar in many respects to much of our Great Plains area.

Throughout equatorial Africa some new and little-known groups, related to the durras, are the leading types. Forms of the Roxburghii group also occur commonly, while kafirs and sorgos are rare. All these tropical forms are late in maturing.

In Abyssinia and throughout the Sudan these new durra-like groups predominate. The Roxburghii group diminishes in importance, while kafirs and sorgos disappear as native types. Few of the local varieties are immediately adapted to our conditions.

In North or Mediterranean Africa only durra groups are found. Those forms found in Egypt are Sudanese; the white durra in the

Barbary States is nearly identical with that of southwestern Asia, and doubtless has resulted from the Arab invasion of Africa.

In all of southwestern Asia, including Asia Minor, Syria, Arabia, Turkestan, and perhaps a part of Persia, the single variety is a white durra, equivalent to our American form.

India contains a bewildering confusion of little-known forms. Many of them approximate the durra group; many are forms of shallu, the type of the Roxburghii group; while some represent entirely new groups of sorghum. A large number tested in this country have proved very poor yielders of grain.

East China and Manchuria are the home of a new group, the kowliangs, with several well-marked varieties. One sorgo variety has long been cultivated at the mouth of the Yangtze River. All these are well adapted to growth under the conditions obtaining in our sorghum belt.

The larger islands near the coast of Asia show a few forms, apparently derived from the mainland.

Europe received a sorghum variety from India during the first century, A. D. Only two or three forms of the sorgo type had been obtained, either through importation or evolution, up to about one hundred and thirty years ago. Only broom corn and a few sorgos are now found there.

No cultivated sorghums are native to the New World. Probably the earliest introduction was the Guinea kafir in the West Indies.

Scattering introductions have appeared in the United States since early colonial days. With the exception of broom corn, none was permanent until the arrival of the sorgo group about fifty-five years ago, followed by the durras and kafirs about twenty years later, shallu about twenty years ago, and the kowliangs recently.

BOTANICAL HISTORY AND CLASSIFICATION.

Sorghum was first known in Europe as *Milium indicum*, or Indian millet, in reference to its origin. Many similar names were applied later.

The common name sorghum, or sorgo, was derived more than three hundred and sixty years ago from the Latin word "surgo," meaning to rise or tower, in reference to the height of sorghums in comparison with that of other crops.

During the sixteenth, seventeenth, and eighteenth centuries the European forms were named and described, with occasional figures, by many pre-Linnean botanists.

The earliest accepted binomial is *Holcus sorghum* L., 1753.

By the middle of the nineteenth century fully thirty botanical species had been described from cultivated forms and about sixty binomial combinations had been made.

Only a part of these so-called species can be identified with existing available forms to-day.

Since about 1850 the differing forms of cultivated sorghums have been regarded as botanical or horticultural varieties. Descriptions have commonly been drawn from the heads and seeds only, ignoring the characters of the plant.

During the past half century numerous classifications of varying scope and completeness have been constructed. Any satisfactory classification must take account of the habit and characters of the entire plant and have regard for natural groups.

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U. S. DEPARTMENT OF AGRICULTURE.
BUREAU OF PLANT INDUSTRY—BULLETIN NO. 176.
B. T. GALLOWAY, *Chief of Bureau.*

SEEDS AND PLANTS IMPORTED

DURING THE PERIOD FROM JULY 1 TO SEPTEMBER 30, 1909:

INVENTORY No. 20; Nos. 25718 TO 26047.

ISSUED APRIL 23, 1910.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1910.

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[Continued on page 3 of cover.]

U. S. DEPARTMENT OF AGRICULTURE.
BUREAU OF PLANT INDUSTRY—BULLETIN NO. 176.
B. T. GALLOWAY, *Chief of Bureau.*

SEEDS AND PLANTS IMPORTED

DURING THE PERIOD FROM JULY 1 TO SEPTEMBER 30, 1909:

INVENTORY No. 20; Nos. 25718 TO 26047.

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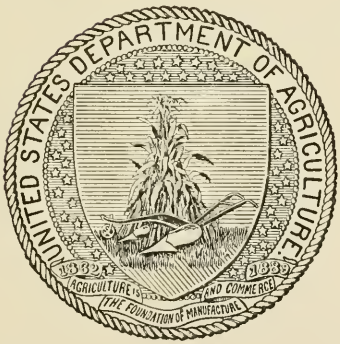

WASHINGTON:
GOVERNMENT PRINTING OFFICE,
1910.

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SEEDS AND PLANTS IMPORTED DURING THE PERIOD FROM JULY 1 TO SEPTEMBER 30, 1909: INVENTORY NO. 20; NOS. 25718 TO 26047.

INTRODUCTORY STATEMENT.

This inventory, covering the first quarter of the fiscal year from July 1 to September 30, 1909, contains 329 introductions. The first quarter has always been light, so far as the number of introductions is concerned. This quarter's introductions have been unusually so, owing to the fact that no explorers were in the field and changes in the office force interfered with regular correspondence; further, to the fact that only those introductions deemed of special interest are being included, those considered of minor importance being recorded in the office files only.

Of unusual interest in this inventory might be mentioned the following introductions:

Numbers 25858 and 25859 cover the seeds of the rattan palms which supply the valuable material for the manufacture of cane-seated chairs, street-car seats, baskets, etc., and whose cultivation as a tropical crop seems to have been given very little attention. The ability of these climbing palms to thrive in dense jungles is believed to be worthy the attention of tropical planters in the Western Hemisphere.

An importation of seeds of the "Queensland nut," *Macadamia ternifolia* (No. 25845), calls attention to the possibilities of cultivating this plant in parts of California and southern Florida. Trees are now growing in southern California which have borne nuts for the past two seasons. The Macadamia is being cultivated in Queensland and New South Wales, and, according to our information, the nuts are very well liked in Sydney, where they retail for as much as a shilling a pound.

In order to aid in the experiments with the horse bean, *Vicia faba*, which are being carried on by the Office of Forage-Crop Investigations, a collection of this important winter legume, adapted to the mild winters of the Southwestern States, has been gathered together from India, Egypt, Holland, Hungary, China, Kashmir, and Spain, and it is hoped that more definite information can be secured regarding the adaptability of this crop to our southwestern country.

The "Monketaan" stock melon (No. 25934) comes to us recommended by Mr. Lounsbury and Mr. Thornton, of the Department of

Agriculture of Cape Colony, as a plant worthy of being given unusual attention. According to their statements, this melon, which is of the nature of a watermelon, is quite distinct from the well-known Tsama melon, which grows on the west side of the Kalihari desert. This is found on the east side of the desert and is remarkable for the high yield of melons to the acre. As many as 150 tons have been produced to the acre, 75 tons being not at all unusual.

The interest in new varieties of mangos has become general enough in Florida to warrant our calling particular attention to the "Pahutan" mango (No. 25940), introduced by Mr. William S. Lyon from the Philippines. Although not as large a fruit or as small seeded as some of the East Indian mangos, it fruits early and is enormously prolific (which some of the East Indian varieties are not). According to Mr. Lyon its sweetness and juiciness are unapproached by any other of the many Filipino mangos he has eaten. Its thick skin will probably make it a good shipper.

The oriental *Myrica nagi* has been introduced under No. 25908. This extremely interesting fruit plant, whose dark wine-colored fruits are exceedingly ornamental, has not been given the attention which it deserves. There seem to be a number of varieties of this fruit, and, although it is a slow-growing tree and late coming into bearing, it is deserving of a trial in California and northern Florida.

The great value of a variety of cherry which is hardier in fruit bud than other cherries is conceded by the horticulturists of the North western States. Those who are breeding or experimenting with cherries will therefore be interested in the introduction of *Prunus tomentosa* (No. 25880), which has been especially recommended by Professor Macoun, of the Experimental Farm at Ottawa, Canada. Trees of this species have been placed in the Upper Mississippi Valley Plant Introduction Garden at Ames, Iowa, for further trial and propagation.

Of especial interest and problematic value is a collection of peach, apricot, and cherry seeds from the Himalayas (Nos. 25894 to 25896). The Indian bael fruit (Nos. 25879, 25889, 25890, and 25912) is one which may prove valuable for making sherbets and for the flavoring of soft drinks. A collection of varieties of tropical corn, representing some of the best work done by the Harvard Experiment Station in Cuba; a collection of oats from Algeria, Palestine, Sweden, and Turkey for the oat breeders; and a wild olive, *Olea foveolata* (No. 25846), from the East London district of Cape Colony, are also worthy of special mention.

David Fairchild,
Agricultural Explorer in Charge.

Office of Foreign Seed and Plant Introduction,
Washington, D. C., December 24, 1909.

INVENTORY.

25718 to 25722.

From Cartago, Costa Rica. Presented by Mr. C. Wercklé. Received July 2, 1909. Seeds of the following; descriptive notes by Mr. Wercklé.

25718. Anacardium occidentale L. **Cashew.**

"These seeds are from the best and largest varieties I could find; red, yellow, and tawn color, the latter are the best. They are from the large grove of Don Rafael Yglesias, in the Cazalar."

25719. Cucurbita moschata Duch.

"*Pipian.* Most prolific pumpkin of the Pacific coast. Full; white fleshed."

25720. Carica papaya L. **Papaw.**

"Good, very large variety."

25721. Carica peltata Hook. & Arn.

"*Suara.* Fruit very small, globular, full (no cavity), sweet, and fragrant. For crossing. Eaten with the seeds as Granadilla. Ovary full, on account of formation of cellular tissue on the funiculus the funiculi of the center of the placenta are very long. Pulp soft, skin very thin."

Distribution.—A native of Central America, found on the coast of Nicaragua and Costa Rica.

25722. Carica papaya ♀ × peltata ♂

"Small, sweet, fragrant fruits, not full or solid as the *Suara.*"

25723 and 25724.

From Baroda, India. Presented by Mr. B. F. Cavanagh, superintendent, State Gardens. Received July 3, 1909.

Seeds of the following:

25723. Terminalia bellerica (Gaertn.) Roxb.

See S. P. I. No. 25541 for description.

25724. Phyllanthus emblica L.

"A small deciduous tree of the family Euphorbiaceæ, found in China, Japan, India, and elsewhere. The unripe fruit, formerly official in medicine, is known commercially as emblic myrobalans and with the leaves and bark is used in tanning. The leaves have been found to contain 18 per cent tannin and the bark 12.6 per cent. Introduced for trial in the Southern States." (*W. W. Stockberger.*)

Distribution.—A large tree, native of tropical India, China, and the Malay Archipelago.

25725 to 25728.

From Baroda, India. Presented by Mr. B. F. Cavanagh, superintendent, State Gardens. Received July 6, 1909.

25725 to 25728—Continued.

Seeds of the following:

25725. STIZOLOBIUM sp.

25726 to 25728. DOLICHOS LABLAB L. **Bonavist bean.**

25726. Black. **25728.** Small red.

25727. Large red.

25729. PHASEOLUS LUNATUS L.

From Antigua, Leeward Islands, West Indies. Presented by Mr. S. Jackson, curator, Government Botanic Station. Received July 3, 1909.

"*Barbuda bean.*"

25730 and 25731. AVENA spp. **Oat.**

From Jerusalem, Palestine. Presented by Mr. E. F. Beaumont. Received July 6, 1909.

Seeds of the following:

25730. AVENA STERILIS L.

25731. AVENA SATIVA L.

Grown from Jaffa seed.

25732. STIZOLOBIUM sp.

From Lawang, Java. Presented by Mr. M. Buysman. Received July 10, 1909.

Black seeded.

25733. MEDICAGO SATIVA L. **Alfalfa.**

From Bridgeport, Kans. Grown on the farm of Mr. Carl Wheeler. Numbered for convenience in recording distribution, July 12, 1909.

"A plant selected for leafiness and seed production from same field which produced S. P. I. No. 19508. Grown at the Department greenhouse under Agros. No. 20." (*J. M. Westgate.*)

25736. ZEA MAYS L. **Corn.**

From Pretoria, Transvaal, South Africa. Presented by Prof. J. Burtt Davy, government agrostologist and botanist, Transvaal Department of Agriculture. Received July 16, 1909.

"*Hickory King.* A strain now being developed in South Africa." (*Davy.*)

25738. SACCHARUM OFFICINARUM L. **Sugar cane.**

From Buitenzorg, Java. Presented by Dr. M. Treub, director, Department of Agriculture. Received July 2, 1909.

"Arrows of one of our best varieties of sugar cane (G. Z. No. 247). Rather a large percentage of these seeds do not germinate." (*Treub.*)

25740. PANICUM PALMAEFOLIUM Koen.

From Pretoria, Transvaal, South Africa. Presented by Prof. J. Burtt Davy, government agrostologist and botanist, Transvaal Department of Agriculture. Received July 19, 1909.

"I do not consider this one of our best grasses, but it is a useful sort in shady places, in comparatively warm districts, and in forest glades." (*Davy.*)

Distribution.—A native of tropical Africa, and extending to the Cape.

25742 to 25752.

From Bavaria, Germany. Presented by G. & S. Heil, Tückelhausen, near Würzburg, Bavaria, through Mr. Charles J. Brand. Received June, 1909.

Seeds of the following:

25742 and 25743. HORDEUM DISTICHON NUTANS Schubl. **Barley.**

25742. *Heil's Hanna No. 4.*

25743. *Heil's Hanna No. 2.*

25744 and 25745. HORDEUM DISTICHON L. **Barley.**

25744. *Original Franconian No. 1.*

25745. *Heil's Improved Franconian.*

25746 and 25747. HORDEUM DISTICHON NUTANS Schubl. **Barley**

25746. *Heil's Hanna No. 1.*

25747. *Heil's Hanna No. 3.*

25748. TRITICUM AESTIVUM L. **Wheat.**

Rimpau's Red Schlanstetter Summer.

25749 and 25750. AVENA SATIVA L. **Oat.**

25749. *Svalöfs Ligowo.*

25750. *Beseler No. 2.*

25751. TRIFOLIUM PRATENSE L. **Red clover.**

German.

25752. BETA VULGARIS L. **Sugar beet.**

Remlingen.

25753. STIZOLOBIUM sp.

From Calcutta, India. Procured by Mr. William H. Michael, American consul-general, who purchased the seed from Mr. S. P. Chatterjee, seedsman. Received July 23, 1909.

Mottled brown and black.

25754. CITRULLUS VULGARIS Schrad. **Watermelon.**

From Tamsui (Daitotei), Formosa, Japan. Presented by Mr. Carl F. Deichman, American consul. Received July 26, 1909.

"Seeds of a watermelon growing in the island of Formosa, which has a fairly good flavor and I believe with proper cultivation could be much improved in quality. The meat of the melon is a very pretty shade of yellow, from lemon to light-orange color, and the size averages about 12 inches in diameter. It would, no doubt, be quite acceptable in the larger restaurants of New York, where there is always a demand for something out of the ordinary. It is not rare here." (*Deichman.*)

25755 to 25757. STIZOLOBIUM spp.

From Reduit, Mauritius. Presented by Dr. P. Boname, director, Agricultural Station. Received July 26, 1909.

Seeds of the following:

25755. Black.

"This is the most extensively cultivated and seems to be the most vigorous." (*Boname.*)

25756. Greenish yellow.

25757. Yellowish, mottled with brown.

25758 to 25774. ZEA MAYS L. **Corn.**

From Ecuador. Presented by Mr. H. R. Dietrich, American consul-general, Guayaquil, Ecuador. Received July 10, 1909.

Seeds of the following; descriptive notes by Mr. Dietrich.

25758. "Maiz amarillo grueso de Chillo (thick, yellow Chillo maize). Grown near Quito, Ecuador, at an elevation of about 8,500 feet, in rich, black, loamy soil. Does well with moderate moisture and is considered to produce better than any other variety grown in Ecuador."

25759. "Maiz blanco (white maize). Grown near Quito, Ecuador. Not quite as productive as some other varieties. It is claimed a good grade of meal may be made from it."

25760. "Maiz morocho blanco (white 'twin' maize). Grown on the hacienda 'Montezerin,' parish of Guayllabamba, near Quito, Ecuador. Elevation, 7,500 feet; moderately warm climate; sandy loam soil, very moist on account of heavy rains. Produces fairly well."

25761. "Maiz morocho grueso de Chillo, blanco (thick 'twin' Chillo maize, white). Grown near Quito, Ecuador. Large, white, and hard; grown at an elevation of 8,500 feet. Rich, black soil; moderate rainfall; produces well."

25762. "Maiz morocho blanco is a type of the hard maize and is distinctive by the better quality of its chemical composition. It acquires greater proportions than other kinds and is as productive as the best varieties grown in Ecuador, but is somewhat slow in its growth and more dependent upon the conditions of the soil than other varieties. From this, it is claimed, comes the variety belonging to the hotter climates. This variety is grown in a different locality in Ecuador than numbers 25760, 25761, and 25763."

25763. "Maiz morocho amarillo is a type of the hard maize and is distinctive by the better quality of its chemical composition. It acquires greater proportions than other kinds and is as productive as the best varieties grown in Ecuador, but is somewhat slow in its growth and more dependent upon the conditions of the soil than other varieties. From this, it is claimed, comes the variety belonging to the hotter climates. This variety is grown in a different locality in Ecuador than numbers 25760 to 25762."

25764. "Maiz amarillo (yellow maize). Grown at Tumbaco, east of Quito, Ecuador, at an elevation of 8,000 feet. Soil, sandy loam; average rainfall; produces well."

25765. "Maiz amarillo (yellow maize). Grown on the hacienda Tina, parish of Conocoto, near Quito, Ecuador, at an elevation of 9,000 feet, in black soil. Does well with moderate rainfall."

25766. "Maiz delgado amarillo (thin, yellow maize). From parish of Quinche, near Quito, Ecuador. Grows in mixed or black sandy soil at an elevation of about 8,000 feet when abundant rain falls."

25767. "Maiz delgado pintado (thin, painted maize). From parish Pomasqui, near Quito, Ecuador. Elevation 8,000 feet; sandy soil; average rainfall; produces well."

25768. "Maiz del indio (the Indian's maize). Grown on the table-lands in the interior of Ecuador."

25769. "Maiz Cangil. Grown on the table-lands in the interior of Ecuador."

25770. "Maiz amarillo de Chillo (yellow Chillo maize). Grown on the table-lands in the interior of Ecuador."

25758 to 25774—Continued.

25771. "Maiz negro (black maize). Grown on the table-lands in the interior of Ecuador."

25772. "Maiz amarillo comun (common yellow maize). Grown on the table-lands in the interior of Ecuador."

25773. "Maiz Chulpi. Grown on the table-lands in the interior of Ecuador."

25774. "Mixed corn grown on the low land near Guayaquil. Used for all purposes for which corn may be used."

25775. JATROPHA sp.

From Vera Cruz, Mexico. Presented by Mr. William W. Canada, American consul. Received July 23, 1909.

"This seed came from a tree that grows wild in the lowlands of this district, is very abundant, and apparently also very rich in oil. The local name is *Duraznillo*, and its commercial value, if any, is unknown here." (*Canada.*)

25776. LAWSONIA INERMIS L.

From Ancon, Canal Zone, Panama. Presented by Mr. H. F. Schultz, horticulturist. Received July 23, 1909.

"This plant has proved very valuable here as an ornamental and flowering shrub. The individually small and rather insignificant yellow flowers form a compact, and yet graceful, panicle and are produced in great masses between the small fine foliage. The plant often produces flowers the first year and abundantly after that. The fragrance is very strong, somewhat resembling that of *Cestrum nocturnum*, and, like the latter, is exhaled even more strongly in the evenings, from which characteristic it has obtained its local name *Dama del noche*.

"Although I do not know whether this plant has ever been used for the manufacture of perfume I should think that it would be suitable for that purpose in frost-free regions of the United States." (*Schultz.*)

"Known as henna, is a shrub long cultivated in the Orient, especially in Egypt and Arabia, where it is used for a variety of purposes. The flowers serve as a perfumery material by virtue of a volatile oil which they contain, having an odor said to closely resemble that of the tea rose. Besides their use in applications to wounds, sores, etc., the leaves are used in some regions to color the finger nails red. The root is astringent." (*R. H. True.*)

Distribution.—Probably a native of the northern part of Africa and western Asia; generally cultivated throughout the warmer parts of Asia and Africa.

25777. ZIZYPHUS JUJUBA (L.) Lam.

From Paris, France. Purchased from Vilmorin-Andrieux & Co. Received July 27, 1909.

Procured as a stock for *Zizyphus sativa*, Chinese date. See S. P. I. Nos. 23439 to 23446 for description.

25778 to 25781. GLYCINE HISPIDA (Moench) Maxim. **Soy bean.**

From Buitenzorg, Java. Presented by Dr. M. Treub, director, Department of Agriculture. Received July 19, 1909.

Seeds of the following:

25778. Black.
25779. Yellow.
25780. Yellow.
25781. Brown.

25782 and 25783. Albizzia spp.

From Buitenzorg, Java. Presented by Dr. M. Treub, director, Department of Agriculture. Received July 24, 1909.

Seeds of the following:

25782. Albizzia stipulata Boiv.

A large, deciduous, fast-growing tree, whose wood is used for manufacturing cart wheels, wooden bells, cabinetwork, and furniture, as well as for fuel; the branches are used for fodder, and the trunk yields a gum, which is used for sizing paper. It is a native of India and the Malay Archipelago, and widely distributed in tropical and subtropical Asia.

25783. Albizzia moluccana Miq.

A tree with large compound leaves, and bearing flowers in small globular heads. The stamens are long and form an ornamental ball around the head of the flowers. The pods are long and strap shaped. It is a native of the Molucca Islands.

25784. Avena sterilis L. Oat.

From Mustapha-Alger, Algeria. Presented by Dr. L. Trabut, Government Botanic Gardens. Received July 26, 1909.

"Variety *sub-sativa*. A cultivated oat developed by utilizing the spontaneous mutations of *Avena sterilis*." (*Trabut.*)

25785 to 25788.

From Amani, Hafen Tanga, German East Africa. Presented by Dr. A. Zimmermann, Royal Agricultural Institute. Received July 24, 1909.

Seeds of the following:

25785 to 25787. Vigna unguiculata (L.) Walp. **Cowpea.**

25785. Reddish brown.

25786. Brown, speckled with black.

25787. Mottled brown.

25788. Pennisetum americanum (L.) Schum. **Pearl millet.**

25797 and 25798.

From Buenos Aires, Argentina. Presented by Dr. Carlos Thays, director, Botanical Garden. Received July 19, 1909.

Seeds of the following:

25797. Aspidosperma quebracho-blanco Schlecht. **Quebracho-blanco.**

"An evergreen tree of the family Apocynaceæ, native of Argentina. The leaves are said to contain 27 per cent tannin. The bark, variously estimated as containing from 2 to 11 per cent tannin, has been used in leather making. The bark contains also 6 alkaloids, one of which, aspidiospermine, is regarded as of most importance as a drug." (*W. W. Stockberger.*)

Distribution.—A large tree, native of the valley of La Plata River in Argentina.

25798. Schinus huigan Molina.

"This tree, of the family Anacardiaceæ, is a native of South America, and is closely related to the 'pepper tree' cultivated in California. It has been said to yield 19 to 20 per cent tannin, and according to Siewert the leaves are used in South America as a tanning material." (*W. W. Stockberger.*)

Distribution.—A native of South America, being found in Brazil, Argentina, Uruguay, Chile, and Peru.

25799 to 25802.

From Saigon, Cochin China. Presented by Mr. Jacob E. Conner, American consul. Received July 30, 1909.

Seeds of the following:

25799. CANANGA ODORATA (Lam.) Hook. f. & Thom. **Ilang ilang.**

See S. P. I. No. 22744 for description.

Distribution.—A native of Java and the Philippine Islands, and cultivated in India and other tropical countries.

25800. CRINUM ASIATICUM L.

"I consider this one of the most ornamental plants I know for a lawn or a large jardinière." (*Conner.*)

Distribution.—Native and cultivated throughout tropical India and Ceylon.

25801. DIPTEROCARPUS DYERI Pierre.

"*Dau song nang.*"

Distribution.—A large tree of the valley of the Donnai River, in the region around Saigon, Cochin China.

25802. DIPTEROCARPUS PUNCTULATUS Pierre.

"*Dau do.*"

Distribution.—Same as No. 25801.

25803. CAESALPINIA NUGA (L.) Ait.

From Luzon, Philippine Islands. Presented by Mr. William S. Lyon, Manila, P. I. Received July 30, 1909.

"A very attractive and sweet-scented, flowered, scandent shrub." (*Lyon.*) See S. P. I. No. 20944 for previous introduction and description.

Distribution.—A native of the southern part of Asia, and extending through the Malay Archipelago and Polynesian Islands to Australia.

25804 to 25807. MEDICAGO SATIVA L. **Alfalfa.**

From Mitchell, S. Dak. Presented by Prof. W. A. Wheeler, through Mr. Charles J. Brand. Received July 31, 1909.

Seeds of the following:

25804. "(South Dakota No. 162.) *Grimm* alfalfa, crop of 1908. Originally grown at Külsheim, near Tauberbischofsheim, Baden, Germany. (See S. P. I. No. 24767.) Brought to Carver County, Minn., in 1857, and grown there since 1858. Present sample grown at Mitchell, S. Dak., in 1908, from seed secured in Carver County, Minn., in 1904, and grown at Highmore, S. Dak., 1905 to 1906. Highmore seed taken to Mitchell, S. Dak., in 1907, where it has since been grown. The 1907 crop of this same strain, grown at Mitchell, S. Dak., is under experiment under P. L. H. Nos. 3329 and 3331." (*Brand.*)

25805. "(South Dakota No. 164.) Acclimatized *Turkestan* alfalfa, crop of 1908. Originally imported from Tashkent, Turkestan, in 1898, under S. P. I. No. 991. Grown at Brookings, S. Dak., from 1898 to 1904. Brookings seed taken to Highmore, S. Dak., and grown there from 1905 to 1906. Highmore seed taken to Mitchell, S. Dak., and grown there since 1907. The 1907 crop of this number is under experiment under P. L. H. No. 3330." (*Brand.*)

25804 to 25807—Continued.

25806. "(South Dakota No. 167.) Of unknown origin. Purchased from a seed dealer at Hartford, S. Dak., in 1894, and grown near Baltic, S. Dak., from 1894 to 1904. Baltic seed grown at Highmore, S. Dak., from 1904 to 1906. Highmore seed grown at Mitchell, S. Dak., from 1907 to the present time. Seed of the 1906 crop is under experiment under S. P. I. No. 19969 and P. L. H. No. 3251. The 1907 seed is under experiment under S. P. I. No. 22946 and P. L. H. No. 3332. The present sample and S. P. I. No. 25537 are of the 1908 crop. (The so-called *Baltic* alfalfa.)" (*Brand.*)

25807. "(South Dakota No. 240.) Acclimatized *Turkestan* alfalfa, crop of 1908. This sample was grown from the same parent seed as No. 25805, South Dakota No. 164. This strain of Turkestan presents one of the most striking examples of acclimatization yet encountered. Seed of the original importation, S. P. I. No. 991, was grown at Highmore, S. Dak., from 1899 until 1906. Highmore seed was taken to Mitchell, S. Dak., in 1901, where it has since been grown. The present sample and S. P. I. No. 25607 are of the 1908 seed crop, grown at Mitchell. The 1906 seed crop, grown at Highmore, is under experiment under P. L. H. No. 3252." (*Brand.*)

25816. Tacca pinnatifida Forst.

From Quilimane, Zambesia, Portuguese East Africa. Presented by Mr. O. W. Barrett, Director of Agriculture, Lourenço Marquez, Mozambique, Portuguese East Africa. Received July 31, 1909.

"Semicultivated plant having 3 to 5 Amorphophallus-like leaves from a cluster of smooth, thin-skinned, roundish corms and a corymbose cluster of greenish flowers on the summit of a naked, yellowish, erect stipe (some 3 to 4 feet high, about twice height of leaves). Corms edible. The natives use it in a variety of ways—like potatoes and dry it in the form of a coarse flour. Habitat, gardens (and vicinity) of natives in Zambesia district. Native name, *I'lide.*" (*Barrett.*)

Distribution.—Widely distributed in Africa, India, Australia, and the Pacific islands.

25817. Barosma crenulata (L.) Hook. **Buchu.**

From Cape Town, South Africa. Presented by Mr. Charles P. Lounsbury, government entomologist, Department of Agriculture. Received August 2, 1909.

"Buchu succeeds best if sown in time and treated in the same way as nursery transplants. It naturally grows in amongst large rocks, so that the roots go into the ground at the side of the rocks or large stones; this keeps the roots cool, and the ground holds moisture longer. Buchu stands here at 1,500 to 4,000 feet elevation." (*Lounsbury.*)

"This is a shrub about 3 feet high bearing short-petioled, opposite leaves, which vary in form from narrowly oval to lanceolate, with crenate margins and with the surface marked by pellucid oil glands. The leaves form a drug, official in many lands, in America under the name of *buchu leaves*, valued for their diaphoretic, diuretic, and tonic properties. They contain from 1 to 2 per cent of a volatile oil. The plant occurs uncultivated in the vicinity of Cape Town, South Africa." (*R. H. True.*)

25822 to 25831. **Gourd.**

From Nice, France. Presented by Hon. Dulany Hunter, consul-general. Received August 3, 1909.

Seeds of the following:

25822 to 25824. Lagenaria vulgaris Ser.

25822. Ornamental, spiral shaped, climbing.

25823. Ornamental, bottle shaped, climbing.

25824. Bottle shaped.

25822 to 25831—Continued.

25825. Luffa cylindrica (L.) Roemer.

Ornamental, sponge, climbing.

25826 to 25830. Lagenaria vulgaris Ser.

25826. Ornamental, stick shaped, grim.

25827. Ornamental, pointed end, climbing.

25828. Ornamental, siphon shaped, climbing.

25829. Ornamental, climbing. From Corsica, Bachouela.

25830. Ornamental.

25831. Cucurbita pepo L.

"The 'Festival des Gougourdons' is held here in the spring, and these seeds are from gourds which are exhibited there. The nurseryman states that the seeds should be planted in a flowerpot and not transferred until the plant is about to throw out a few leaves; that the soil should be well manured, but not too abundantly, as in that case the gourd does not become sufficiently dry to be used for holding liquids. When the plants are large enough they are tied to trellis work so they can be exposed to the sun. They need comparatively little water, and the fruit should be protected from heavy dews by being kept covered at night. The seeds are planted in the spring, and the fruit, which dries on the plant, is ready to be gathered by the end of September or early in October. The peasants at Cimiez produce pipes and other articles of odd shapes by wrapping parts of the gourd before it has ripened with soft pieces of cloth, and are thus enabled to bend them into the form they wish to produce. In this way the covered parts do not develop freely, and, remaining soft, can be bent into the desired shape." (*Hunter.*)

25841 to 25844. Allium cepa L. **Onion.**

From Teneriffe, Canary Islands. Presented by Mr. Solomon Berliner, American consul. Received August 5, 1909.

Seeds of the following:

25841. *Bermuda Red.*

25842. *Wildpret's Golden.*

25843. *Bermuda White.*

25844. *Crystal-Wax.*

25845. Macadamia ternifolia F. Muell.

From Wellington Point, Queensland, Australia. Presented by Mr. J. Pink. Received August 2, 1909.

For description, see S. P. I. No. 18382.

Distribution.—A small tree, native of the eastern part of Australia, being found in the valleys of the rivers in the southeastern part of Queensland, and in New South Wales.

25846. Olea foveolata E. Meyer.

From East London district, Cape Colony, South Africa. Presented by Mr. Charles P. Lounsbury, government entomologist, Department of Agriculture, who procured the seeds from Mr. Henry G. Flanagan, F. L. S., of "Prospect," Komgha district, for whom they were collected by a Mr. Oliver. Received August 9, 1909.

"The district where these seeds were collected has a warm, temperate climate with about 30 inches of rainfall, chiefly in the summer months." (*Lounsbury.*)

Distribution.—A tall shrub, native of the woods of the southern part of Africa.

25847. PROTEA GRANDIFLORA Thunb.

From Grahamstown, Cape Colony, South Africa. Presented by Mr. J. Medley Wood, director, Botanic Gardens. Received July 31, 1909.

A shrub or small tree, 3 to 10 feet high, with oblong, sessile, shining leaves, and large, white flower heads, which resemble a globe artichoke in appearance.

25848. SCHLEICHERA TRIJUGA Willd. **Kussum.**

From Dhamtari, Raipur, India. Presented by A. E. Lowrie, esq., Deputy Conservator of Forests. Received August 12, 1909.

"This seed ought to be sown in fairly rich sandy loam, in boxes, to begin with. When the young plants are about 9 inches high they should be planted out in a well-drained sandy soil." (*Lowrie.*)

"This Indian tree, known as the lac tree or Ceylon oak, is one of the sources of shellac. The wingless female of the lac insect (*Tachardia lacca* Kerr) with its piercing mouth parts punctures the bark of the young, tender twigs, from which the shellac flows down the stems and hardens. The seeds yield a fatty oil, the so-called 'Macassar' oil, which contains free hydrocyanic acid, as well as the glycerides of oleic, palmitic, and arachidic acids. The wood, which is much used, is hard and durable and takes a polish. The sapwood is white, the heartwood is reddish brown." (*R. H. True.*)

Distribution.—A large tree, native throughout central and southern India, and extending through the Malay Archipelago to the Philippines.

25849 to 25856. AVENA SATIVA L. **Oat.**

From Madrid, Spain. Presented by Mr. A. Ramirez, El Hogar Español. Received August 13, 1909.

Seeds of the following:

25849. Open, white, panicle.

25850. Large, white.

25851. Common.

25852. Large, white, panicle.

25853. Black, open, panicle.

25854. Black.

25855. Black oat with pendent panicle.

25856. Yellow.

25857. VIGNA UNGUICULATA (L.) Walp. **Cowpea.**

From Venice, Italy. Presented by Dr. Angelo Sullam, of Portotolle, Taglia di Po, Italy, through Mr. Haven Metcalf. Received August 14, 1909.

Black-Eye.

25858 to 25860.

From the Philippine Islands. Presented by Mr. William S. Lyon, Manila. Received August 16, 1909.

Plants of the following:

25858 and 25859. CALAMUS sp.

25858. From Batanes Islands.

25859. From Palawan Island.

. "*Palasan*".

"All the good rattans I know are strictly equatorial and not to be thought of in any of our occidental possessions other than the Canal Zone. I have crossed

25858 to 25860—Continued.

25858 and 25859—Continued.

the Isthmus twice. The yellow clay still impresses my memory with its stickiness and with its similarity to the yellow clays of Mount Canlaon (Negros), where I think perhaps I have seen the most riotous growth of *Palasan*—our best rattan. As I remember it, the rainfall on the Isthmus is probably about 2,400 to 2,500 mm. (94 to 98 inches). If it is less than 2,000 mm. (about 79 inches), I think rattans would not do much, although at Perak the precipitation is less and they raise some good, long-jointed canes.

"For environment the rattans want jungle and plenty of it. My remembrance of the zone is that the hills were unbroken jungle. Calamus must have a thick mass of medium-sized vegetation to scramble over.

"There is a single feature of Calamus culture which differentiates it positively from every other sylvan product with which I am acquainted. It is (if there be any such thing) an exception to the law of selection. All are fit to survive under conditions where all other species except those fortuitously well placed would succumb. No amount of crowding or shading seems to choke off a young rattan. Its progress is tedious under adverse conditions, but it struggles up till it gets light and then nothing but the bolo or cutlass can hold it back. In planting practice, this gives it a supreme advantage over most plants. Further, it eliminates the bugbear and expense of jungle clearing, a matter which is to be heavily reckoned. I am not prepared to give a thesis on rattan culture, but close observation of its behavior in our smooth bamboo (cana boho), which makes a thicket impervious to any animal except a wild pig and which is voracious enough to choke out every other kind of vegetable life except Calamus, inspires me with exceptional credulity to believe it can be grown more nearly as a purely spontaneous crop than any economic product known, not excepting common timber trees.

"I am not advocating complete neglect; removal of a fallen limb or a rank herbaceous weed, or an occasional slash with a bolo, would probably accelerate growth, but it is not an essential factor to success. The best commercial rattans, both Calamus and Damonorpas, are spiny as hedgehogs and immune from the raids of even deer. Best of all, they are renascent from the butt, and the same land and same planting may be cut over in six or seven years for a second time. There are two very serious drawbacks to a very general adoption of rattan planting for profit. One, their shy fruiting habits and consequent scarcity of seed; the other, slow development.

"The fruits are eaten by birds, and seeds can only be obtained where they are concealed from the birds. All the species, I fancy, are, as seeds, of fugitive vitality. This is not only my own limited experience, but is evidently that of European seedsmen—those who are specialists in palm seeds, and who rarely offer them for sale. As most of the species until they reach the sprawling age are remarkably ornamental, far more so than most palms, I can only explain their absence from catalogues of tropical ornamentals upon these grounds.

"I can give you no idea of the time required to yield a crop. I only know that the crop is slow, very slow. The renewal crop is rapid. I have seen canes on cut-over lands which had been stripped four years before. I think in five or six years at most, and on poor lands, a second crop can be depended upon. A seedling crop, perhaps, in 10 years." (*Lyon.*)

25860. Livistona whitfordii Beccari.

"This is far more compact, bushy, and ornamental than *Livistona rotundifolia*." (*Lyon.*)

Distribution.—A native of the province of Tayabas in the island of Luzon.

25861. MANGIFERA INDICA L. **Mango.**

From Trinidad, British West Indies. Presented by Mr. F. Evans, acting superintendent, Botanic Gardens. Received August 18, 1909.

Seeds.

Julie. See S. P. I. No. 21515 for previous introduction and description.

25862. CITRUS NOBILIS Lour.

From Saigon, Cochin China. Presented by Mr. Jacob E. Conner, American consul. Received August 14, 1909.

Seeds.

"A very fine, flat, green-skinned mandarin orange, a little larger than the ordinary ones of this type. The flesh is quite reddish in color, and the flavor is a combination of that of the ordinary flat and the round loose-skin oranges." (*Conner.*)

25863 to 25866.

From Nairobi, British East Africa. Presented by Mr. and Mrs. C. E. Akeley, Chicago, Ill., through Mr. Charles J. Brand. Received August 17, 1909.

Seeds of the following economic plants, grown by the Wakamba tribe of natives:

25863. PENNISETUM AMERICANUM (L.) SCHUM. **Pearl millet.**

Cat-tail millet, called by the Wakamba tribe *Mwee.*

25864. ELEUSINE CORACANA (L.) Gaertn. **Ragi millet.**

Wimbi.

25865. CAJAN INDICUM Spreng.

A species of bean. Mr. Akeley states that this is a bean of rapid growth which the natives use for wood.

25866. ZEA MAYS L. **Corn.**

A variety of Indian corn grown by the Wakamba tribe.

25867. CITRULLUS VULGARIS Schrad. **Watermelon.**

From Merw, Russian Turkestan. Presented by Capt. M. L. Cummins, Sixteenth Infantry, U. S. Army, Fort Crook, Nebr. Received August 13, 1909.

"The melon is orange colored and not reddish inside, and in my opinion was the best I have ever eaten. The seeds came from a melon I had in Merw in the south-central part of Turkestan." (*Cummins.*)

25868 to 25869.

From Lourenço Marquez, Portuguese East Africa. Presented by Mr. O. W. Barrett, Director of Agriculture. Received August 14, 1909.

25868. (Undetermined.)

"(No. 29, June 28, 1909.) From Nhamacurra, Quilimane, Portuguese East Africa. Native name (Chizena) 'Mucuipile.' A forest plant growing in sandy soil. Rhizome (attaining a weight of several pounds), irregular in shape; starch content moderate. Height 2 to 4 feet." (*Barrett.*)

25869. GLADIOLUS sp.

"(No. 28, June 28, 1909.) From Nhamacurra, Quilimane, Portuguese East Africa. Native name (Chizena) 'Tumbanimasa.' A plant of the low moist lands of the Zambezi Valley. Flower pale yellow, medium size, opening nearly downward. Bulb, pale-brown coat, yellow inside. Height 2 to 3 feet." (*Barrett.*)

25870. STIZOLOBIUM sp.

From Barbados, British West Indies. Presented by Mr. Francis Watts, Commissioner of Agriculture, through Mr. John R. Bovell, superintendent. Received August 4, 1909.

"Bengal bean."

25871. TRIFOLIUM PRATENSE L. **Red clover.**

From Huntsville, Ala. Purchased from Mr. Clarendon Davis. Received August 6, 1909.

"Seed of red clover, which has proved disease resistant at Huntsville, where red clover usually suffers severely. This strain was developed from surviving plants." (*J. M. Westgate.*)

25874. PASSIFLORA EDULIS Sims. **Passion fruit.**

From Sydney, Australia. Presented by Van Dyk & Lindsay, importers, 209 Washington street, New York, N. Y. Received August 20, 1909.

See S. P. I. No. 12899 for description.

Distribution.—A native of Brazil, and cultivated in other tropical countries.

25876. PHASEOLUS LUNATUS L.

Presented by Mr. O. W. Barrett, Director of Agriculture, Lourenço Marquez, Portuguese East Africa. Received August 21, 1909.

"(No. 30, July 24, 1909.) A slender-stem, climbing, bean-like plant received from Mr. Henry Brown, of Mlanje, Nyasaland, and stated by him to have been brought from the Kongo basin. Grown at Lourenço Marquez. Flowers in short racemes, whitish." (*Barrett.*)

25879. BELOU MARMELOS (L.) W. F. Wight. **Bael.**

From Lahore, Punjab, India. Presented by Mr. W. R. Mustoe, superintendent, Government Archæological Gardens. Received July 31, 1909.

See S. P. I. No. 24450 for description.

25880. PRUNUS TOMENTOSA Thunb.

From Ottawa, Canada. Presented by Mr. W. T. Macoun, horticulturist, Central Experimental Farm. Received at the Upper Mississippi Plant Introduction Garden, Ames, Iowa, July 29, 1909.

"(Ames Ac. No. 458, 1909.) 'This cherry appears to be hardier in fruit bud than any other cherry we have at the Experimental Farm, and as it makes good preserves and is fair eating I think it quite an acquisition.' (*Macoun.*) For more complete description, see Annual Report, W. T. Macoun, horticulturist, Central Experimental Farm, Ottawa, Canada. 1908 : 106." (*S. A. Beach.*)

Distribution.—A shrub or small tree, occurring in the northwestern part of India, northern China, Manchuria, and Japan.

25884 to 25887.

From Cochin China. Secured by Mr. Xavier Salomon, chief, Botanical Garden, Saigon, and presented by Mr. Jacob E. Conner, American consul. Received August 24, 1909.

25884 to 25887—Continued.

Plants of the following:

25884 to 25886. From Cape St. Jacques.

25884. CINNAMOMUM LOUREIRII Nees.

"This species is supposed to be one of the most valuable sources of some of the best cinnamon that comes to our market." (*R. H. True.*)

Distribution.—A native of the mountains of Cochin China and of Japan.

25885. ATALANTIA sp.

25886. TETRACRONIA CYMOSA Pierre.

Distribution.—A shrub or small tree, native of the mountains in the vicinity of Binh Dinh, French Indo-China.

25887. GARCINIA MANGOSTANA L. **Mangosteen.**

From Saigon. "This delicious fruit is about the size of a mandarin orange, round and slightly flattened at each end, with a smooth, thick rind, rich red-purple in color, with here and there a bright, hardened drop of the yellow juice which marks some injury to the rind when it was young. As these mangosteens are sold in the Dutch East Indies—heaped up on fruit baskets or made up into long, regular bunches, with thin strips of braided bamboo—they are as strikingly handsome as anything of the kind could well be, but it is only when the fruit is opened that its real beauty is seen. The rind is thick and tough, and in order to get at the pulp inside it requires a circular cut with a sharp knife to lift the top half off like a cap, exposing the white segments, five, six, or seven in number, lying loose in the cup. The cut surface of the rind is of a most delicate pink color and is studded with small yellow points formed by the drops of exuding juice. As you lift out of this cup, one by one, the delicate segments, which are the size and shape of those of a mandarin orange, the light-pink sides of the cup and the veins of white and yellow embedded in it are visible. The separate segments are between snow-white and ivory in color and are covered with a delicate network of fibers, and the side of each segment where it presses against its neighbor is translucent and slightly tinged with pale green. As one poises the dainty bit of snowy fruit on his fork and looks at the empty pink cup from which it has been taken, he hardly knows whether the delicate flavor or the beautiful coloring of the fruit pleases him the more, and he invariably stops to admire the rapidly deepening color of the cut rind as it changes on exposure to the air from light pink to deep brown. The texture of the mangosteen pulp much resembles that of a well-ripened plum, only it is so delicate that it melts in your mouth like a bit of ice cream. The flavor is quite indescribably delicious and resembles nothing you know of, and yet reminds you, with a long after-taste, of all sorts of creams and ices. There is nothing to mar the perfection of this fruit, unless it be that the juice from the rind forms an indelible stain on a white napkin. Even the seeds are often partly or wholly lacking, and, when present, are generally so thin and small that they are really no trouble to get rid of. Where cheap and abundant, as in Java, one eats these fruits by the half peck, and is never tired of them. They produce no feeling of satiety, such as the banana and the mango do, for there is little substance to the delicate pulp." (*David Fairchild.*)

25888 to 25890.

From India. Presented by Mrs. Effie Pyle Fisher, Igatpuri, through Miss Audrey Goss. Received August 25, 1909.

25888 to 25890—Continued.

Seeds of the following:

25888. FERONIA ELEPHANTUM Correa.

"This is the wood-apple of India and Ceylon, a deciduous tree with pinnate leaves, bearing a fruit about the size of an orange, but with a very thick, woody rind.

"The pulp of the fruit is acid and aromatic and is sometimes eaten by the natives of India; it is also used to prepare a jelly much resembling that made from black currants, but this jelly is said to have a very astringent taste.

"This plant is allied to the bael fruit of India, *Belou marmelos*, and is being grown to hybridize with that species, and also for trial as a stock upon which to graft it." (*W. T. Swingle.*)

Distribution.—A medium-sized tree, found in the sub-Himalayan forests. from the Ravi eastward, and throughout the greater part of the plains of India, being more frequent in the moist tracts of Bombay, Madras, Bengal, and Burma than in northern India.

25889. BELOU MARMELOS (L.) W. F. Wight. **Bael.**

Both of the above are from the state gardens, Baroda.

25890. BELOU MARMELOS (L.) W. F. Wight. **Bael.**

From Mr. George Hodson, florist and seedsman, Bangalore.

See S. P. I. No. 24450 for description of *Belou marmelos*.

25891 to 25893.

From Ootacamund, India. Presented by Rev. G. N. Thomssen, American Baptist Telugu Mission, Bapatia, South India. Received August 20, 1909.

Seeds of the following:

25891. RHODOMYRTUS TOMENTOSA (Ait.) Wight.

The Downy myrtle, or Hill gooseberry, is a handsome evergreen shrub, with broad glossy leaves, pink flowers larger than those of a peach and lasting for several weeks, and dark-purple berries about the size of a cherry and tasting like a raspberry. The fruits are eaten raw, and used for making jam and jelly. (*Adapted from Bailey.*)

Distribution.—An evergreen shrub, native of the southeastern part of Asia, extending from India through China, the Malay Archipelago, and the Philippines to Japan.

25892. PHYSALIS PERUVIANA L.

From plants of ten years' select cultivation of the South African Cape gooseberry in India.

Distribution.—A native of Peru and cultivated throughout the Tropics.

25893. (Unidentified.)

White straw flowers growing wild on the Nilgiris.

25894 to 25897.

From Simla, India. Presented by Mr. E. Cotes, Indian News Agency, through Mr. Frank N. Meyer. Received August 27, 1909.

Seeds of the following:

25894. AMYGDALUS PERSICA L. **Peach.**

25895. PRUNUS ARMENIACA L. **Apricot.**

25894 to 25897—Continued.

25896. PRUNUS PUDDUM Roxb. **Cherry.**

Distribution.—A tree, native of the northern part of India, extending from the Indus to Sikkim, usually at an elevation of between 2,500 and 7,000 feet.

25897. PYRUS sp. **Pear.**

"These seeds were collected from wild Himalayan fruit trees, growing at an elevation of 7,000 feet about Simla." (*Cotes.*)

25898 to 25901. VICIA FABA L. **Horse bean.**

From United Provinces, India. Presented by Mr. T. F. Main, Deputy Director of Agriculture, Poona, Bombay Presidency. Received August 27, 1909.

"The three last numbers seem to be of one variety collected from different villages, while the first is quite different." (*Main.*)

25902 and 25903. VICIA FABA L. **Horse bean.**

From Egypt. Presented by Mr. George P. Foaden, secretary, Khedivial Agricultural Society, Cairo. Received August 28, 1909.

Seeds of the following; notes by Mr. Foaden.

25902. *Saidi.* Planted in Upper Egypt under basin irrigation.

25903. *Beheri.* Planted in Lower Egypt under canal irrigation.

These are the same variety, but recognized by the cultivators as being cultivated under two different systems of irrigation.

25904 to 25907. VICIA FABA L. **Horse bean.**

From Friesland Province, Holland. Presented by Dr. M. Greshoff, Koloniaal Museum, Haarlem, Holland. Received August 6, 1909.

25908. MYRICA NAGI Thunb.

From Tangsi, China. Procured by Rev. Alexander Kennedy, at the request of Mr. Frank N. Meyer. Received August 21, 1909.

See S. P. I. Nos. 22977 and 22904 to 22906 for descriptions.

"These seeds are for stocks; better varieties are to be grafted on to them later. The plants are exceedingly hard to transplant. The trees thrive wherever the loquat does." (*Meyer.*)

25909. MIMUSOPS KAUKI L. **"Adam's-apple."**

From Lawang, Java. Presented by Mr. M. Buysman, Hortus tenggerensis. Received August 26, 1909.

A large tree, native of India, the Malay Archipelago, and Australia. The fruit resembles *Zizyphus jujuba* in flavor, and is edible. The wood is red, fine grained, and easy to work.

25910. VIGNA UNGUICULATA (L.) Walp. **Cowpea.**

From Entebbe, Uganda, British East Africa. Presented by the Botanical, Forestry, and Scientific Department. Received August 26, 1909.

Brown. There seem to be several varieties in this lot.

25911 and 25912.

From Lal Bagh, Bangalore, India. Presented by Mr. G. A. Gammie, Imperial Cotton Specialist, Kirkee, India, at the request of Mr. J. Mollison, Inspector-General of Agriculture in India. Received August 30, 1909.

25911 and 25912—Continued.

Seeds of the following:

25911. FERONIA ELEPHANTUM Correa. **Wood-apple.**

See No. 25888 for description.

25912. BELOU MARMELOS (L.) W. F. Wight. **Bael.**

"The bael fruit is highly prized by natives of this country and is an article of food with them, especially in Upper India. A very nice cooling drink is made from its pulp in the hot season, also a nice jam is prepared out of it. The unripe and the ripe fruit and its rind, root, leaves, and flowers are used medicinally. Sherbet made from the ripe fruit is very valuable in cholera and bowel complaints." (*Gammie.*)

25913 to 25920.

From Hangchow, China. Presented by Rev. W. S. Sweet, Wayland Academy, Baptist Missionary Union, Eastern China Mission. Received August 2, 1909.

Seeds of the following; notes by Mr. Sweet.

25913 and 25914. VICIA FABA L. **Broad bean.**

25913. Green. **25914.** Brown.

Vine 2 feet long. Used as human and animal food and also for firewood. Ripe from April to May.

25915. DOLICHOS LABLAB L. **Bonavist bean.**

White. Known as the crested bean; vine 4 to 6 feet; used as human food and for firewood; ripe in September.

25916. PHASEOLUS ANGULARIS (Willd.) W. F. Wight. **Adzuki bean.**

Red. Used for food; vine small and fine, 6 inches high; ripe in September.

25917. PISUM SATIVUM L.

Tall vine; ripe from May to June; used for forage.

25918. VIGNA SESQUIPEDALIS (L.) W. F. Wight.

Black. Tall vine.

25919 and 25920. GLYCINE HISPIDA (Moench) Maxim. **Soy bean.**

25919. Yellow. Vine 1 foot high; ripe from November to December. The cheese made from this bean forms a large element of food here; if adapted to American taste a profitable business could be established in the States.

25920. Black. Ripe from June to August; used the same as No. 25919.

25921 to 25925.

From Leh, Ladakh, Kashmir, British India. Presented by Mr. Rassul Galwan. Received August 27, 1909.

Seeds of the following; notes by Mr. Galwan.

25921. TRITICUM AESTIVUM L. **Wheat.**

Before this seed is sown the field is put under water till the ground is wet a half foot deep. Then wait ten to twenty days, till the ground is fairly dry and the seed can be sown. The ground must be neither too wet nor too dry. Before the seed is sown manure is spread about one-half inch thick over the ground. The first water is given when the wheat is about 2 inches high, the ground being soaked about one-half foot deep. After it becomes dry again a second watering is given. It is better to wait a little too long than to water too quickly.

25921 to 25925—Continued.

Up to the third watering care must be used, after that the wheat is strong and water can be given at any time it is dry. The more water given the better the crop.

25922. Hordeum sp. **Hull-less barley.**

The method of sowing this is the same as for wheat, the only difference being that this can be sown late, as it ripens in two to three months. Flour is made from it, but the bread is not as good as the bread made from wheat flour. Most people use it, therefore, as Suttoo, which is made as follows: First, wash the barley in cold water, after waiting one day put in the sunshine and let dry. Then fry in an iron pot until brown, then take to a mill and have it ground into flour, which is eaten with Ladaki tea; some eat it with water, some mix it with butter, sugar, and tea, for there is no need to cook it again. If hot things can not be had, it can be eaten with cold water.

25923. Vicia faba L. **Horse bean.**

Brownish black.

25924. Lathyrus sativus L.

This is sown with wheat. It can be sown in places a little cold, and there is no need to use any manure. The sowing methods are the same as those used in sowing wheat. The seed is sown about the 10th of May and ripens in about three months. At the sowing time the seed needs more moisture than wheat or it will not grow well.

25925. Pisum arvense L. **Field pea.**

This is sown in hot places, and does best in sandy soil. It is sown here about the 20th or the 25th of April, and ripens in about three months. The method of sowing is the same as that of wheat, except that no manure is put on the field. If manured the plants grow very large but without beans. The stalks are good to feed to animals. Before sowing, the ground should be wetter than when wheat is sown or the beans will not do well.

25926 and 25927.

From Igatpuri, India. Presented by Mrs. Effie Pyle Fisher, through Miss Audrey Goss. Received August 31, 1909.

Seeds of the following:

25926. Feronia Elephantum Correa.

See No. 25888 for description.

25927. Anona reticulata L. **Custard-apple.**

See S. P. I. No. 5210 for description.

25928. Colchicum sp.

From Alpine heights of Geovjé Dagh, above Hassanbeyli, Amanus Mountains. Presented by Mrs. F. A. Shepard, Aintab, Turkey. Received August 19, 1909.

"A wild colchicum having large, pink, very showy blossoms in September. Fruit ripens in May." (*Shepard.*)

25929 to 25931. Cucumis melo L. **Muskmelon.**

From Columbia, Mo. Presented by Mr. G. C. Broadhead. Received August 21, 1909.

25929 to 25931—Continued.

Seeds of the following:

25929. 1903 crop.

25930. 1908 crop.

25931. 1909 crop.

"Between 1825 and 1835 the Rev. Albert Holladay, of Virginia, was Presbyterian missionary to Persia. He brought to America seeds of a cantaloupe. My father raised this melon in Virginia, and in 1836 brought seed to St. Charles County, Mo., where he raised it until his death in 1853. Relatives and friends have since raised it. I have for thirty years, also my brother William, living at Clayton, St. Louis County. The melon raised in Virginia and in Missouri for ten or twenty years was smaller and sweeter than that raised since. It seems the first was not much over 4 inches in diameter and good to the outer rind. The melon now is as much as 6 inches in diameter and has at least a one-half of an inch of rind. When ripe it pulls off easily and generally has a red gum at stem where it breaks. A good melon of this kind is still better than most others and we call it the 'Persian cantaloupe.'" (*Broadhead.*)

25932. MEDICAGO SATIVA L. **Alfalfa.**

From Aintab, Turkey. Presented by Mrs. F. A. Shepard. Received September 3, 1909.

"This seed was collected in the arid regions about Aintab, about 3,500 feet above the sea and 100 miles inland. There is scarcely any rain for five months in the year. The plant is not planted for pasturage, but grows upon wild lands, where sheep and goats browse." (*Shepard.*)

25934. CITRULLUS VULGARIS Schrad. **Watermelon.**

From Robertson, Cape Colony, South Africa. Presented by Mr. Charles P. Lounsbury, government entomologist, Cape of Good Hope, Department of Agriculture, Cape Town, who procured the seeds from Mr. E. A. Visser, manager of the Experiment Station at Robertson. Received September 4, 1909.

Monketaan.

"Mr. Visser says this plant yielded melons at the rate of 75 tons an acre on the station grounds without any special care, and that the melons keep well and are excellent stock food. They weigh about 30 pounds each and have a firm, sweetish, somewhat tough pulp. The rind is mottled pale and dark green like common watermelons, as a rule, but is sometimes whitish in this strain. The seeds do not separate readily and no one seems to be trying to save more than he needs for himself, so there is little chance of buying a supply unless it is ordered a year ahead. Mr. Jack, who was director in the department here and is now farming, is trying in vain to get seed for 100 acres, which at least indicates that the merits of the crop appeal to him. Mr. Thornton, our agriculturist, tells me the plant has long grown to the west of Kuruman on the east side of the Kalihari desert. (The small Tsama melon sent to the United States grows on the west side.) He thinks it was probably cultivated there by natives in bygone days, but now it grows wild. Some years ago he got down seeds and had them planted near Graaff Reinet. Farmers of the district soon appreciated the value of the melon and took to its cultivation as a stock food. It is said on good authority to have yielded as high as 150 tons an acre around there, the ground becoming almost obscured by the fruits. The strain introduced to the Robertson station is from Graaff Reinet way, not direct from the desert, and Thornton thinks there is a possibility that it is not quite true to type; but if it is not, it is an improvement on the original he thinks.

25934—Continued.

"It seems to me that this or other of the South African melons should be more worth cultivating in arid parts of the West than the thornless prickly pear. Of course the melons want water, but much of what they get they store away for months." (*Lounsbury.*)

"One of our experimenters of the *Monketaan* melon has just reported that the return per acre of melons amounted to 103 tons, and it was found that on an average there were two melons to every square yard of land. This melon, according to the analysis we have already had made, is high in feeding value and promises to take a leading part in some of our stock districts." (*Extract from letter of Mr. R. W. Thornton, government agriculturist, Cape Town Department of Agriculture, August 24, 1909.*)

25935. Vicia villosa Roth. **Hairy vetch.**

From Moscow, Russia. Purchased from Immer & Son, through Prof. N. E. Hansen, Agricultural Experiment Station, Brookings, S. Dak., while traveling as an agricultural explorer for this Department. Received September 7, 1909.

25936. Rosa sp. **Rose.**

From Ogden, Utah. Presented by Miss Pearle Cramer, United States Department of Agriculture, Forest Service. Received September 7, 1909.

Yellow. "This rose, so far as I have been able to ascertain, is native only to Utah where it grows in great profusion." (*Cramer.*)

25937. Oryza sativa L. **Rice.**

From Tsangsheng, Kwangtung Province, near Canton, China. Presented by Mr. Stuart J. Fuller, American vice consul-general-in-charge, Hongkong, for whom it was procured by Mr. Leo Bergholz, American consul-general at Canton. Received September 9, 1909.

"*Szemiu*, the translation of which means 'Best quality refined.' The Chinese rice merchant states that the exportation of this rice in any quantity or in samples is forbidden by the Chinese Government." (*Amos P. Wilder, American consul-general, Hongkong, China.*)

25938 to 25940. Mangifera indica L. **Mango.**

From Philippine Islands. Procured by Mr. William S. Lyon, Gardens of Nagtajan, Manila, P. I. Received September 8, 1909.

Seeds of the following standard varieties:

25938. *Carabao.*

See S. P. I. Nos. 24927 and 25659 for previous introductions.

25939. *Pico.*

See S. P. I. No. 24170 for previous introduction.

25940. *Pahutan.* "From my viewpoint this is the best, *not* horticulturally, other than being a vigorous grower, early fruiter, and enormously prolific. Its very serious defects—small size, scanty flesh, and excessively large seed—are from my point of view fully offset by a smoothness, sweetness, juiciness, and flavor unapproached by any other. I have eaten the famous *Alphonso* mango in Calcutta and do not consider it ace high with *pahutan*. *Pahutan* further has a very thick rind. This, while still further diminishing its scanty flesh, probably adds to its shipping qualities." (*Lyon.*)

25941. ELEPHANTORRHIZA ELEPHANTINA (Burch.) Skeels.

Acacia elephantina Burch., Trav., vol. 2, p. 236. 1824.
Acacia elephantorrhiza (Burch.) D. C., Prod., vol. 2, p. 457. 1825.
Elephantorrhiza burchellii Benth., Hook Journ. Bot., vol. 4, p. 344. 1842.

Although Burchell is given as the authority in De Candolle's Prodromus for the specific name *elephantorrhiza*, the name he really used and under which he gave an excellent botanical diagnosis is that here recognized.

From Pretoria, Transvaal, South Africa. Presented by Prof. J. Burtt Davy, director, Transvaal Department of Agriculture. Received September 10, 1909.

Seeds.

"All grazing animals, wild and domestic, are exceeding fond of this plant. It has long, succulent roots and an underground stem. It does not shoot until rather late in the summer, seldom before December, and its stems are killed again by the first frosts of May. The seed-pods are still green when the frost comes, and the seeds not ripe, but they are so well protected by the strong, leatherlike pod, that the frost can not hurt them, and they ripen in the pod long after the stem that bore them has been killed by the frost. The roots are used for tanning leather." (*Mrs. Barber, in Harvey, Flora Capensis, vol. 2, p. 277.*)

Distribution.—South Africa. Common in grassy places between the Klipplaat and Zwartkey rivers in Cape Colony. It occurs also in the Cradock and Queenstown districts in Cape Colony, and is reported from the "Zooloo Country." Originally described from near "Klaawater" in the southern part of Orange River Colony.

25942. BERBERIS SANGUINEA Franch.

From Nancy, France. Purchased from V. Lemoine & Sons. Received September 14, 1909.

"This is a little-known species from China and appears to be closely allied to *Berberis nepalensis*. The blooms are said to be deeper orange-red than any other species. These plants are imported for hybridizing purposes." (*W. Van Fleet.*)

Distribution.—A native of dry stream beds in the province of Szechwan, China.

25950 to 25953. VICIA FABA L.

From Valencia, Spain. Presented by Mr. Charles S. Winans, American consul. Received September 8, 1909.

Seeds of each of the following:

25950 to 25952. **Broad bean.**

25950. *Caliente.* Light brown.

25951. *Panesca.* Purplish brown.

25952. *Murciana.* Dark purple.

25953. **Horse bean.**

Favon. Purplish black.

25956 and 25957.

From Amanus Mountains, Turkey in Asia. Presented by Mrs. F. D. Shepard, Adana. Received September 9, 1909.

Seeds of each of the following:

25956. AVENA SATIVA L. **Oat.**

25957. VICIA ERVILIA (L.) Willd. **Bitter vetch.**

25959 to 25962. ZEA MAYS L. **Corn.**

From Central Soledad, Cienfuegos, Cuba. Presented by Mr. Robert M. Grey, Harvard Botanical Experiment Station. Received September 21, 1909.

Seeds of the following; notes by Mr. Grey.

25959. *Harvard selected flint.* This is our surest cropper, best keeper, and, being free from surface starch, less subject to attack from weevils and ants.

25960. *Selected white flint Cuban.* This is used as a sweet or table corn, is early, and a small-cob variety.

25961. *Hybrid purple cob (Cuban dent × Cuban flint).*

25962. *Cuban dent.*

These two last are the varieties commonly cultivated here and are very productive.

The above have been under selection for six years. The husk of all closes tight at the apex, a great prevention and safeguard against insects.

25963. VICIA FABA L. **Horse bean.**

From Magyaróvár, Hungary. Presented by The Plant Culture Experiment Station, requested from Prof. A. Cserhati. Received September 22, 1909.

"These seeds are planted in the spring and mature in about one hundred days. The plants grow from 35 to 40 centimeters high. The beans are ground up and make a very nutritive food for stock. The fodder is of hardly any value." (*Gyárfás.*)

25964. GOSSYPIUM HIRSUTUM L. **Cotton.**

From Nyasaland Protectorate, British Central Africa. Presented by Mr. J. Stewart J. McCall, Director of Agriculture, Zomba. Received September 27, 1909.

"Seed of Upland cotton which received the first prize at the recent show at Blantyre. I think you will consider it a very high-class hirsutum cotton, and it is very gratifying as we received 6d. to 7d. per pound for it at the Manchester market." (*McCall.*)

25965. VIGNA UNGUICULATA (L.) Walp. **Cowpea.**

From Pretoria, Transvaal, South Africa. Presented by Prof. J. Burtt Davy, government agrostologist and botanist, Transvaal Department of Agriculture. Received September 10, 1909.

"Kafir bean." This lot apparently contains several different varieties.

26047. GARCINIA MANGOSTANA L. **Mangosteen.**

From Port of Spain, Trinidad, British West Indies. Presented by Mr. F. Evans, botanical department, Department of Agriculture. Received fall of 1909.

Seeds. See No. 25887 for description.

"The mangosteen will be an unusually good shipper, as tropical fruits go. The small crate of fruits from which these seeds were taken, shipped by Mr. Evans on the 28th of September, was delayed for more than a week in New York and reached Washington on the 19th of October. Even after holding these fruits for five days after arrival in Washington—i. e., twenty-six days from the time they were picked—they were still in an edible condition, although naturally they had lost a good deal of their delicacy and the pulp had begun to adhere to the thick rind. One remarkable feature about these fruits lies in the fact that as they decay the rind hardens until it becomes almost as hard as a rock. I believe it may not be necessary to crate these in shipment on this account. A single rotten fruit may not infect others, as in the case of mangos or other soft-skinned fruits; in fact, as tropical fruits go, it seems to be an ideal shipper." (*David Fairchild.*)

PUBLICATION OF NEW NAMES.

It has been thought desirable to call attention to the new names which it is occasionally found necessary to publish in the inventory by giving a list of such names as they occur. This list will therefore appear in future issues on the page of the inventory preceding the index.

The following name is published in this issue:

25941. Elephantorrhiza elephantina (Burch.) Skeels.

The names given below have been published in preceding issues of the inventory:

21750. Albizzia adiantifolia (Schum.) W. F. Wight.

Bulletin 137 (Inventory No. 14), Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 12.

21797. Sesban bispinosa (Jacq.) Steud.

Bulletin 137 (Inventory No. 14), Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 15.

21820. Xiphagrostis condensatus (Hack.) W. F. Wight.

Bulletin 137 (Inventory No. 14), Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 17.

The correct name for the above is *Miscanthus condensatus* Hack.; the genus Xiphagrostis [Contributions from the U. S. National Herbarium, vol. 9, 1905, pp. 399–400] having been based on a misconception of the type of Miscanthus as established by Andersson in 1856. That author indicated in a note that he did not consider the first species, *M. capensis*, as typical of the genus, and the second species, *M. japonicus*, should accordingly be recognized as the type. The usual application of the generic name Miscanthus therefore remains unchanged.

21824. Phaseolus angularis (Willd.) W. F. Wight.

Bulletin 137 (Inventory No. 14), Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 17.

21893. Chrysanthemum stipulaceum (Moench) W. F. Wight.

Bulletin 137 (Inventory No. 14), Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 21.

22349. Phragmites vulgaris longivalvis (Steud.) W. F. Wight.

Bulletin 137 (Inventory No. 14), Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 46.

22390. Garcinia tinctoria (DC.) W. F. Wight.

Bulletin 137 (Inventory No. 14), Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 50.

22813. Pinellia cochinchinense (Blume) W. F. Wight.

Bulletin 142 (Inventory No. 15), Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 35.

22957. Belou marmelos (L.) W. F. Wight.

Bulletin 142 (Inventory No. 15), Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 48.

23219. Firmiana simplex (L.) W. F. Wight.

Bulletin 142 (Inventory No. 15), Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 67.

23428. Myrciaria edulis (Vell.) Skeels.

Bulletin 148 (Inventory No. 16), Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 14.

23472. Phyllanthus acida (L.) Skeels.

Bulletin 148 (Inventory No. 16), Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 17.

23897. Cryptocarya rubra (Mol.) Skeels.

Bulletin 153 (Inventory No. 17), Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 15.

23963. Brassica pekinensis (Lour.) Skeels.

Bulletin 153 (Inventory No. 17), Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 21.

24087. Callistemma chinensis (L.) Skeels.

Bulletin 153 (Inventory No. 17), Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 27.

24591. Belou glutinosa (Blanco) Skeels.

Bulletin 162 (Inventory No. 18), Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 26.

24631. Gourliea spinosa (Mol.) Skeels.

Bulletin 162 (Inventory No. 18), Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 31.

25546. Claucena lansium (Lour.) Skeels.

Bulletin 168 (Inventory No. 19), Bureau of Plant Industry, U. S. Dept. of Agriculture, 1909, p. 31.

INDEX OF COMMON AND SCIENTIFIC NAMES.

Adam's-apple. See *Mimusops kauki.*
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U. S. DEPARTMENT OF AGRICULTURE.
BUREAU OF PLANT INDUSTRY—BULLETIN NO. 177.
B. T. GALLOWAY, *Chief of Bureau.*

A PROTECTED STOCK RANGE IN ARIZONA.

BY

DAVID GRIFFITHS,
AGRICULTURIST, OFFICE OF FARM MANAGEMENT.

ISSUED APRIL 19, 1910.

WASHINGTON:
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1910.

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BUREAU OF PLANT INDUSTRY—BULLETIN NO. 177.

B. T. GALLOWAY, *Chief of Bureau.*

A PROTECTED STOCK RANGE IN ARIZONA.

BY

DAVID GRIFFITHS,

AGRICULTURIST, OFFICE OF FARM MANAGEMENT.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., January 11, 1910.

Sir: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 177 of the series of this Bureau a manuscript entitled "A Protected Stock Range in Arizona," by Dr. David Griffiths. This paper has been submitted for publication by Prof. W. J. Spillman, Agriculturist in Charge of the Office of Farm Management.

This is the second report upon range investigations in the Santa Rita National Forest in cooperation with the University of Arizona. It portrays the effects of proper protection of the native pastures of the region and shows that results are much more certain of accomplishment by proper management than by attempting reseeding operations.

Respectfully,

A. F. Woods,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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B. P. I.—547.

A PROTECTED STOCK RANGE IN ARIZONA.

INTRODUCTION.

This report is one of progress simply and is necessarily incomplete, the details being purposely omitted. Many essential facts are also left out, because they have been included in a previous bulletin [a] of the series of the Bureau of Plant Industry.

The investigations really date from 1903, when a tract of land 49.2 square miles in area upon the Coronado National Forest was closed to grazing by arrangement with the Forest Service and in cooperation with the agricultural experiment station of the University of Arizona. Since that time another small tract of nearly a section has been inclosed and cooperative arrangements entered into with four ranchers contiguous to the south and east line of the large tract whereby the investigations will be considerably benefited in extent of territory, diversity of conditions, and interpretation of results by practical range operators. The map, figure 1, shows the area covered and the locations of the different pastures. A record of the operation of these areas under different systems of management during the next few years ought to throw important light upon the value of the proper handling of these semidesert lands.

EARLY HISTORY OF THE INCLOSED AREA.

Before the inclosure of this area it was open range, and large herds have fed here for years. The cattle usually come over in the fall from the other side of the mountains and remain until the April round-ups. In the upper portion of the field there was once a ranch of one of the largest cattle companies of southern Arizona, which has always been heavily grazed, but much heavier in times past than during the last few years before the inclosure was made. All in all, it may be said that heavy pasturing was the rule here for many years previous to that time. (Compare the two illustrations shown in Plate I.) A portion of the area farthest from water, mostly on the edge of the perennial-grass

[a] Bulletin 67, Bureau of Plant Industry, U. S. Dept. of Agriculture, entitled "Range Investigations in Arizona." 1904.

area, was grazed only during the wet season when it could be reached by stock. It was therefore in much better condition than that lying closer to the mountains, where water was more convenient.

FIG. 1.—Map of fenced pastures in the Coronado National Forest, compiled from maps by the United States Geological Survey, the Forest Service, and the Bureau of Plant Industry.

HISTORY OF THE AREA SINCE 1903.

The large field was inclosed in June, 1903. By the first of the year 1908 the pastures marked upon the map (fig. 1) *P.*, *R.*, and *MacB.* were sufficiently inclosed to permit the control of stock in them, and the inclosures were completed later. These areas were inclosed by ranchers in cooperation with the Department of Agriculture. The 204-acre pasture was inclosed years ago and has been moderately

FIG. 1.—RANGE LAND INSIDE AND OUTSIDE OF THE FENCED AREA IN JUNE, 1903.

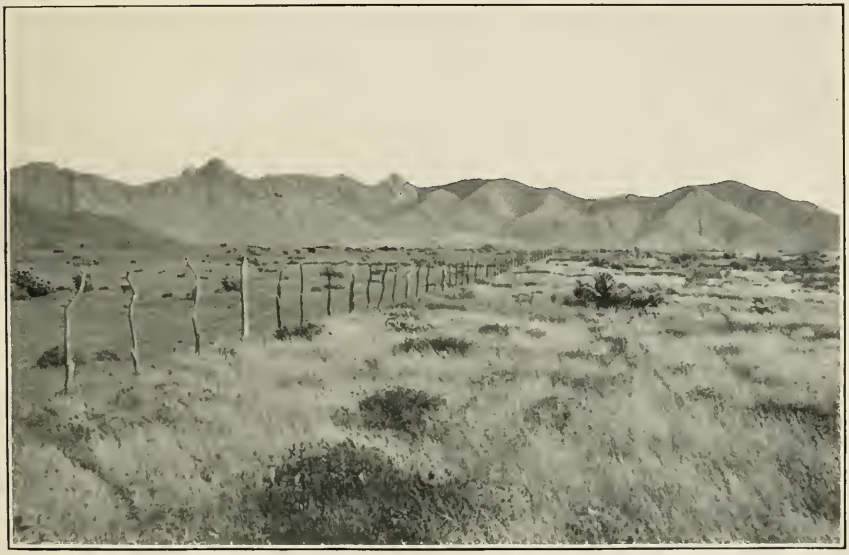

FIG. 2.—RANGE LAND INSIDE AND OUTSIDE OF THE FENCE LINE IN APRIL, 1905.

PASTURES SHOWING IMPROVEMENT DUE TO TWO YEARS' PROTECTION BY FENCING.

stocked ever since. A large part is in heavy brush, and consequently not as productive as it would otherwise be. A few head of stock have been allowed in the 590-acre pasture since it was fenced, but the large area has had no stock upon it since it was inclosed except an occasional stray. The pastures *P.*, *R.*, and *MacB.* have been handled by their owners very much as their judgments dictated, a record being kept in all cases of just what treatment each pasture received.

SURFACE COVERING.

The accumulation of dead herbage upon the surface of the soil of the area takes place very slowly. When the growth first dries up in the fall after a good rainy season there is an accumulation of, perhaps, a thousand pounds of dry matter to the acre. This is enough to make a big fire if ignited shortly after the dry season sets in. If left upon the ground for one year in this climate, however, it largely disappears, from the action of wind and weather, so that the accumulation, while surely taking place from year to year, is very slow. In this inclosure after six years of protection there is in no portion of it a complete ground cover during the entire year. There is, it is true, at the close of the rainy season grass two feet or more high in some places, but, as is characteristic of desert vegetation, it is thin and largely disappears before the next season. In the lower portion of the field, where the annual grasses predominate, the accumulation is next to nothing, but it gradually increases toward the higher level and is most abundant in the extreme southern portion of the inclosure. (See Pl. IV, fig. 2.) The occurrence of a dry year largely obliterates any cover that may have accumulated during the previous season. In short, even after six years of protection there is now in the lower portion of the field practically no ground cover, and in all probability there never has been any. In the upper portion, while the growth increases under protection, there is yet only about half a cover on the ground during the entire year. In the upper country, at an altitude of 3,500 feet and upward, a large accumulation of dead herbage can be kept upon the ground under a good system of management, as is being done in some private and cooperative pastures in the region now, but below this altitude the ground cover is not a factor of much consequence, for the grasses are mostly annual. Of course, upon the swales which receive flood waters the galleta and other grasses make a large growth and protect the surface, but such areas do not occur in the inclosures here described.

It will be seen that the matter of growth is one of distribution of moisture, which is influenced by altitude. As stated elsewhere, the rainfall quoted in this paper is taken in the 204-acre pasture. This point probably receives more rainfall than any portion of the large inclosure, the precipitation decreasing gradually northward until one

reaches a point where it is too light to support the perennial grasses. However, a few miles to the northeast of the field there is an area of lower ground where hay has frequently been cut, but this is due to the spread and accumulation of flood waters over the surface. It is more than probable that the rainfall where the gauge is located is from 1½ times to twice that in the lower (northern) portion of the field, which represents more closely the conditions obtaining around Tucson. Besides, the distribution of rainfall is much better in the upper portion of the inclosure, more frequent rains occurring than in the low altitudes.

CONDITIONS INSIDE AND OUTSIDE OF THE FENCED AREA.

Upon the north and the west sides of the field there is practically no difference between the inside and the outside of the inclosure. There are two reasons for this. The north and northwest portions are the least productive of the field, and in this neighborhood water is a long way off, so that the stock graze here very little. Indeed, there have been but few cattle in the vicinity of the fence from the private pastures to the northwest corner for two years. (See map, fig. 1.) As a consequence, upon the southwest side a small crop of hay was cut on the outside of the fence last year.

On the east side, outside of the inclosure, the pasture is very short, having been grazed for years by horses and sheep. The conditions here are most instructive. The year 1908 was a favorable one and, consequently, in spite of the heavy grazing, some of the valuable perennial grama grasses matured seed to a much greater extent than in former years. This illustrates the extreme persistency of these grasses. They may be greatly abused even in this easily eroded and parched region, but when a favorable season occurs they again make their appearance and will, if husbanded for a few years, regain their supremacy. There is no doubt that there was at least ten times as much growth of these valuable perennials in 1908 as there had been for the previous three or four years. On the whole, there was in 1908 a fairly good crop of vegetation on this badly denuded region tributary to Helvetia, but it consisted in largest measure of the six-weeks' grasses, which are the poorest in the region.

From McCleary's south gate to Helvetia the area next to the government fence is now entirely protected by private holdings. (See map, fig. 1.) Although some of these have been only partially protected from the very excessive grazing of the previous years for somewhat less than twelve months, there is a phenomenal difference between them and the outside range. In one instance an inclosure of nine months' duration can be recognized for a distance of six or more miles even though the area has been grazed moderately all the time.

NATURAL RESEEDING.

Nature is normally profligate in her seed supply. It seems at times, especially with desert plants, that germination will insure seed production; in other words, many plants which have sufficient moisture for germination seldom fail to produce some seed. Indeed, in an average season the annual plants of the desert produce enough seed to restock the same land and insure as large a subsequent crop as the sterile soils can maintain. A small percentage of the more common plants grow each year and in turn produce seed. As an example we might cite *Bouteloua aristidoides*. A season is seldom so dry that some of this grass will not grow and produce seed. The plants may be a foot high and yield very little seed, or the spikes in a favorable year may equal the entire length of the plant in an unfavorable one.

It is different, however, with the perennial grasses. A season which produces an abundance of seed may be followed by one unsuited to the growth of seedlings, and consequently the crop of seed, although it falls to the ground, may be largely lost. Since the Department's operations in the Santa Rita Mountains were begun there have been but two years favorable for reproduction. The season of 1907, although not so prolific as the subsequent one, produced an abundance of seed of *Bouteloua rothrockii* and *Bouteloua bromoides*, two of the most important grasses in this region. This was followed by a very favorable season in 1908. There was consequently an exceptionally good growth of seedlings that season. It is quite possible that the seedlings of these two grasses over the entire areas in which they are peculiarly characteristic would average from four to six to the square foot. These seedling plants were all well established and in thrifty, vigorous growing condition on October 1, 1908.

The condition of these seedlings the next season was not only of scientific interest but of exceeding economic importance. If they all grew to maturity and produced plants the next year as vigorous and large as those that grew on the same area the yield ought to be increased 50 per cent, other conditions being equal. This condition, of course, was beyond the range of probability, because such a yield would be beyond the capacity of these desert lands to produce. As a matter of fact it is doubtful whether the yield of perennials in the upper portion of the field was much greater in 1909 than in 1908, in spite of the large number of seedlings of 1908. Natural selective influences work to thin this stand to the typical thin, scattering, bunchy condition best adapted to maximum production upon arid lands, a principle becoming better and better recognized in the growing of farm crops with small amounts of rainfall. Thin seeding is now recognized to be best under such conditions. The difference

between a good crop and a small one in the perennial-grass region of these deserts is not so much due to a larger number of plants as to larger plants or clumps of plants.

Our experience upon this inclosed tract seems to indicate that the natural restocking of the perennial range by new plants takes place at irregular intervals. The ratio of increase may bear no relation to the quantity of seed produced the previous year. In other words, a favorable season for seed germination following a poor season of seed production may develop vastly more seedlings than one of poor distribution of moisture following an abundant seed production. Since this area was fenced, there has been but one season when the production of perennial-grass seedlings failed almost entirely. On the other hand, there have been but two years in five when a decided increase was noticed, the increase in 1907–8 being enormously greater than any of the others.

ARTIFICIAL RESEEDING.

Many attempts have been made to introduce forage plants in this section, both in the large inclosure and upon the holdings of private individuals in the vicinity. There is but one species that has given any beneficial results. Alfilerilla (*Eurodium cicutarium*) has been tried several times and in various situations. In brushy pastures in the upper foothills it has produced a thick mat of herbage some years, while in others the growth has been poor. All in all it has done well in patches, but only in the most favorable situations, in rather loose soil, where the grazing has been quite heavy and there is open mesquite brush. This plant grows in the winter; consequently, the shade furnished by the mesquite is at a minimum when the plant grows. It has taken four or five years for it to become well established.

In the open foothills, where the best pasture is found, the growth of this plant has been of no consequence. It has been started in several places, and indeed there were patches of it to be found in several situations when the field was inclosed, but even these have not spread. In short, the plant does not appear to be able in this situation to compete with native vegetation when the latter is not grazed. In one locality, along the fence line, there has been for years a patch of a few acres established no one knows how, but probably by sheep. This has been watched with interest, but the growth of alfilerilla has been less under protection than in the open where the land was heavily grazed.

In all, some two hundred species of forage plants have been planted in this inclosure. Many native species were tried, but the vast majority used were of foreign importation. At one time the Office of Forage-Plant Investigations of the Bureau of Plant Industry fur-

nished more than one hundred varieties for testing. In some cases the seed was covered and in others scattered without any further attention. The plan has been, whenever the quantity of seed permitted, to sow one-half in the fall and one-half in the early summer. In some cases the ground was worked up sufficiently to kill about half of the original vegetation.

The net economic result of all this foreign introduction has been practically nil. It is not necessary to go into details regarding these plantings, even to the extent of publishing a list of the seeds planted. Most of the species, in our experience, have never come up, and the few things that did make any growth usually died before seed was produced.

In 1906 large quantities of wild oats (*Avena fatua* and *A. barbata*) were planted in June. Germination was very good, and by the 1st of January, 1907, the plats were promising, but the plants soon dried up, never getting over about 2 inches high. The seed did not germinate until the winter rains set in. The previous year seed of bur clover (*Medicago denticulata*) from California was sown in large quantity and well covered. It started beautifully, but dried up and died in April when about 2 inches high, with no seed production.

Tucolote (*Bromus maximus*) matured a few plants from one of the several seedings made, but seems to have disappeared entirely. This is one of the most aggressive species upon the California ranges. It might not be a detriment here, for it is a winter annual, and therefore would come in competition with only weedy spring plants and would probably have no effect on the crop of forage which comes in summer.

Results in reseeding, so far as these experiments have progressed, can be secured much more satisfactorily by the use of seed of native forage plants than by the use of the seed of plants from foreign countries. But even with these the results are not commensurate with the expense of getting the seed and growing it. Much more satisfactory results have thus far been obtained by husbanding the native vegetation and grazing well within the capacity of the land to maintain stock. In short, so far as information gained from experiments thus far conducted is concerned, these lands, although very badly overgrazed, will return approximately to their original productivity under complete protection in about three average years. Complete protection, however, is not necessary, though of course it will take longer to restore lands to their full productivity when grazing is practiced.

These remarks apply only to the plants already tried, the majority of which had some claim to succeeding in dry situations. It is not impossible that some foreign plants may yet be found which will succeed here, and all which have any chance of success should be tried. But meantime proper handling of the native vegetation is

urged—a system of grazing which it is well within the capacity of the land to maintain.

A number of native grasses have been caused to spread successfully by gathering the seed in advantageous localities and simply scattering it where the ground was badly denuded. Better results have been obtained when seeding was done the last of June or the first of July. When sown in autumn the ants pick up too many of the seeds. Beneficial results have been secured in this way by the use of the seed of *Andropogon saccharoides*, *Bouteloua vestita*, and *B. rothrockii*. Less positive results have been secured by the use of native seed of *Bouteloua curtipendula* and *Leptochloa dubia*. Indifferent results have been secured with *Bouteloua oligostachya*. It should be noted that the last is a very important grass on the east side of the Santa Rita Mountains, but, so far as the writer knows, it does not occur on the northwest side of the divide except in one small, well-established patch. The origin of this is not certain, but it is believed that it was established by seeding done in 1901. It is a beautiful, vigorous growth in a place which was badly denuded at that time.

The above illustrations of the successful use of native species are important and interesting, but they have no applicability to open-range conditions. However, where the land is under fence and seed can be secured in the vicinity without too much expense, improvements can be made in very badly trampled areas. When the roots of the native growth are not completely destroyed, it is questionable whether in such situations as this recuperation would not occur fully as rapidly by proper protection from overgrazing without the use of seed as with it.

It must be remembered that the chances of failure of seed in such a region are very great. It is not necessary to discuss at length the contributing causes. They are many. The most important are the irregularity and the uncertainty of the rainfall.

TEMPORARY CHANGES IN VEGETATION.

The most striking changes in vegetation are those which take place from year to year in annual plants, and this is always noticeable in any region where the annual vegetation predominates. As a concrete example, the growth upon one of the inclosures in 1907 may be compared with that of 1908. In a badly denuded portion of one of the fields a blue-flowered, aster-like composite (*Machalranthera* sp.) was decidedly conspicuous. It was estimated that in 1907 one could have cut with a mower at least 500 pounds of dry matter to the acre from a large area. In 1908 one would have been obliged to cut not less than 30 acres to secure 500 pounds. The only place that the plant grew the second year was along washes and rivulets, which,

FIG. 1.—FIELD OF BOUTELOUA ROTHROCKII IN A GOOD SEASON, 1908.

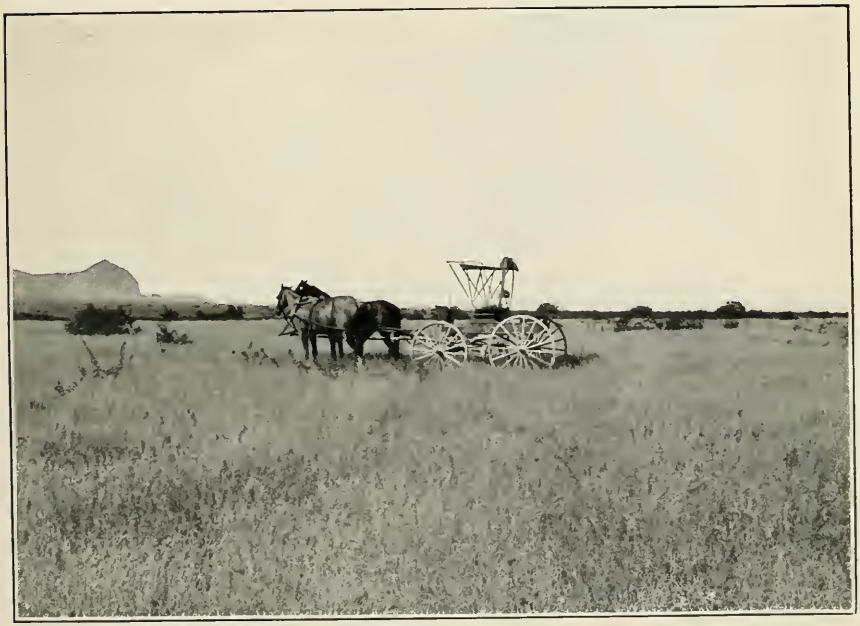

FIG. 2.—FIELD OF BOUTELOUA ROTHROCKII IN A POOR SEASON, 1907.

COMPARATIVE GROWTH OF GRASS ON RANGE LANDS IN A GOOD AND A POOR SEASON.

however, never had water except during a rain. In 1908 this aster-like plant was supplanted by *Bouteloua aristidoides, Aristida bromoides,* and other weedy annual grasses. Besides these, there was a thin and very irregular growth of such valuable perennials as *Bouteloua rothrockii, Bouteloua bromoides, Leptochloa dubia,* and *Bouteloua vestita.* This area was in the 590-acre inclosure (marked U. S. R. on the map, fig. 1). The changes were more noticeable than in the large field because the small field was more completely denuded of its vegetation. It is quite probable that the productive capacity of the small field is much below the average of similar portions of the other field.

But such differences in vegetation, comparing one year with another, are very striking. There has not been one year in ten when there was such a crop of *Plantago fastigiata* throughout the region (see Pl. V, fig. 2) as in the spring of 1901. In the large field, even with similar rainfall, there occurs an ascendency of one plant one year and of another plant another year, and this is more especially true of the growth of the spring season, which is more truly annual. One year the Arizona lupine (*Lupinus arizonicus*) gives its characteristic color to the landscape. Another year may witness the same with reference to *Orthocarpus purpurascens palmeri. Lotus humistratus* may be the abundant species another year, and *Pectocarya linearis* another. In the upper portion of the large inclosure at the present time there is a good stand of perennial grasses. These grow in the relatively humid summer season. During the summer there is a very sparse growth of annuals. In the spring, however, this region which grows grass in summer has its complement of annuals, and the relative abundance of the species varies about the same as it does on the lower portion of the field, where the perennials do not occur.

So far as known, no one has ever offered an explanation for these yearly variations of annual vegetation. The change in the aspect and balance of the species occurs in the annuals only. There has been no change, so far as anyone can see, in the areas of *Bouteloua rothrockii, Bouteloua bromoides, Aristida divaricata,* or *Aristida californica* in the large inclosure since the beginning, excepting a gradual thickening up of the respective species and a consequent shutting out of the annuals. (See Pls. II and III.)

PERMANENT CHANGES IN VEGETATION.

The rancher in this region is only half wrong when he asserts, as he commonly does, that the six-weeks' weedy and low-quality grasses have recently taken the range and driven out what he calls "root grasses," or the more valuable perennials. It is only the last portion of the statement that is false. The perennials, or more valuable

species, have, it is true, disappeared, but they were not driven out by annuals, but, on the contrary, by the rancher's cattle.

The annual grasses of this region, such as *Bouteloua aristidoides* and *Aristida bromoides*, are not much relished by stock. They have harsh, hard glumes which penetrate the flesh. They dry up early, leaving but little substance, and, more than all this, they pull up by the roots when grazed and carry with them sand and dirt. They are therefore not eaten while the perennials are available. When the latter become impoverished by excessive grazing the former flourish. The ranges have therefore at present a larger proportion of weedy annuals, not because the latter are more aggressive, but because the former have been impoverished and to a large extent in many sections killed out by overgrazing.

One thing at least has been conclusively proved in this experiment, i. e., that the perennials which once flourished here and which have been decidedly injured by stock will again regain their ascendency over the weedy annuals when given a measure of protection. The *Bouteloua rothrockii* and *Bouteloua bromoides* areas were not only less productive of these perennial grasses when the inclosure was made but were actually more productive of the annuals *Bouteloua aristidoides* and *Aristida bromoides*. (See Pls. II and III.) The gradual encroachment of the perennials upon the region of annual grasses has been one of the most notable features since the area was inclosed, and is yet in all probability only partially accomplished.

The regaining of ascendency by the perennials is slow here, much slower than in regions favored by a more equitable rainfall. As stated elsewhere, it is only in an occasional season that seed of the perennials appears to find conditions congenial for growth. This, coupled with the fact that the annuals invariably encroach at this altitude whenever the perennials are injured, renders the process of recuperation slow here compared with that in northern regions of more favorable rainfall and a less easily eroded soil.

On the other hand, the increased growth of an even partially protected area is phenomenal. One of the inclosures completed very late in 1907 can be distinguished at the present time for miles by the difference between the character of its vegetation and that of the vegetation outside, and it has been grazed continuously at that, but only moderately.

Last season one of the fields inclosed was as badly grazed as the Macaranthera area already referred to, but grew a fine crop of a yellow annual composite. Although it was in one of the best perennial-grass regions on the west side of these mountains, there was practically no grass there except a poor growth of the six-weeks' varieties. This season there is, of course, after such excessive graz-

FIG. 1.—A CLOSE VIEW OF THE SOUTHEASTERN PORTION OF THE INCLOSED AREA.

FIG. 2.—GENERAL VIEW OF THE SOUTHEASTERN PORTION OF THE INCLOSED AREA.

VIEWS IN THE INCLOSED AREA.

ing, only a moderate growth of the perennials, but at least tenfold as much as there was last year, and a very heavy growth of the annuals. Judging from what has taken place upon the first large inclosure, the annuals will gradually give way to the perennials during the next four or five years and at the same time withstand a considerable amount of grazing.

Below an altitude of about 3,500 feet we come to the desert proper, where the summer grasses are mainly of the annual type, always have been, and probably always will be. Below this altitude the only perennial grasses are those which are favored by occasional irrigation, in long arroyos and swales, where the drainage from higher levels spreads out over them. There is no hope of establishing perennials upon the lower, unirrigated mesa lands. When rains are favorable the low-lying regions will produce some indifferent feed in the shape of annuals, and that is all that can be hoped for them.

PECULIARITIES OF THE FEED.

The appearance of the feed upon the ground is deceptive in any desert country, but more especially in the area described in this bulletin. The growth is invariably thin, but it may be quite tall, especially in favorable years, making difficult an estimate of the quantity of feed produced. This is true of the growth in general upon a desert region. The most deceptive grass of all is the one locally known as black gama (*Muhlenbergia porteri*). (See Pl. IV, fig. 1.) In early days this grass was exceedingly conspicuous, growing in tangled masses 2 to 3 feet high, both in clumps of shrubbery and in the open. The pioneer stockman calculated the productivity upon what he saw of this species, supposing that he was dealing with a grass of ordinary character. But the pioneer saw three or four years' growth, for the culms of this grass are perennial, only the terminal joints dying back each season. When, therefore, an area is unpastured for a time there is actually an accumulation of feed from year to year of this grass and some others, while the ordinary grasses die and grow up again from the roots each year. The deception is really serious, as is readily seen if one mistakes three or four years' growth for one and stocks the land accordingly. This is precisely what has happened in many cases. It is no wonder that some managers of stock companies insisted that the country could not be overstocked, nor, indeed, would it probably be if the production which the pioneer saw could be repeated with certainty each year.

WEEDS.

There are really but two weeds in the inclosure, but they are both somewhat serious. One is one of the rayless golden-rods (*Isocoma coronopifolia*) (Pl. IV, fig. 1), not distantly related to the sheep weeds

and snake weeds of New Mexico, Texas, and northern Arizona. Here this plant has spread upward from the river bottom and now occupies the rocky ridges and mesas between the grassy section and the more level desert lands below. It has thickened and increased perceptibly during the last five years. The rainfall in the region where it is most abundant was very light in 1908, and it consequently made but little growth. No one can tell what the future of this plant may be; it is quite probable that the grasses unmolested would hold their own against its encroachments, but with the grassy vegetation weakened by grazing it may increase to such an extent as to crowd out nearly all of the valuable plants, as is done over thousands of acres in other regions by species of Gutierrezia.

Remedies which are effective and at the same time economically applied in the control of the variety of rayless golden-rod mentioned have not been perfected as yet. Burning in the dry season in summer will kill some species of the group. In other words, if there is sufficient herbage upon the ground to burn during the vegetative condition of these plants they will be killed by burning the land over, but burning during the winter season, when they are dormant, will not kill them.

In the region under consideration the golden-rod referred to has increased mainly below the grassy area, such increase having taken place but partially during the time that the area has been under protection. The encroachment evidently had begun years before. It is not yet thick enough to burn, even during the dormant dry season. Should all the young plants in evidence in 1908 come to maturity, which is rather improbable, it would be thick enough to burn in two or three years. The grasses do not become abundant enough here to allow of burning. The weed is increasing in the lower grassy areas, but principally in that region which now, as probably always, is producing mainly annual grasses. How far it will increase in the perennial-grass areas and how its encroachments within and without the fence will compare can not yet be satisfactorily judged. It must be remembered that it takes very much longer to secure positive results in matters of this kind in this region of scanty rainfall than in more favored localities. There are indications that the plant has about reached the limit of its growth here, as the sheep weeds have elsewhere, and like them has begun to die. In 1909 a large proportion of the plants were dead and none were as vigorous as in previous years, although the season was exceptionally favorable.

The only other real weed is the loco weed (*Lupinus arizonicus*). This is supposed to have done much damage to the horse industry, but does not appear to be as injurious to cattle. So serious is the matter considered that at least one rancher in the vicinity has gone out of the horse business entirely.

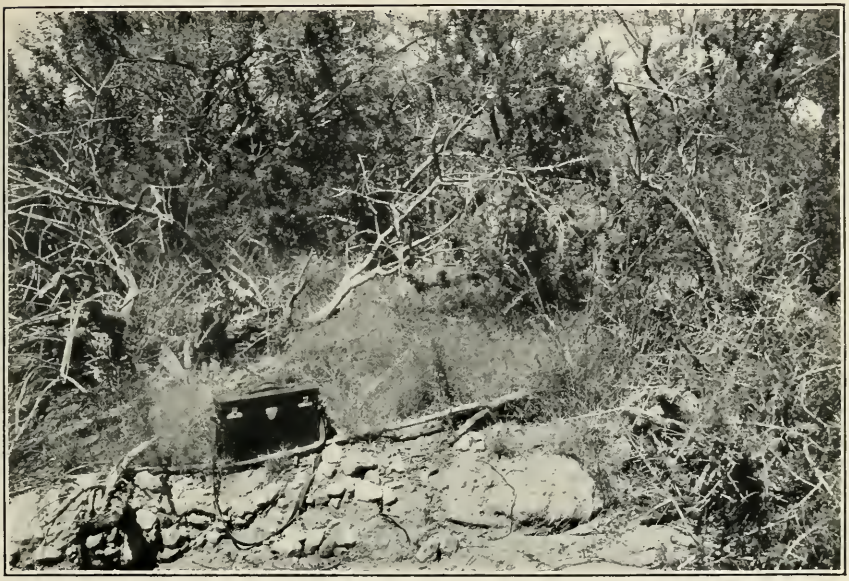

FIG. 1.—MUHLENBERGIA PORTERI GROWING UNDER THE PROTECTION OF A CAT-CLAW.

FIG. 2.—ISOCOMA CORONOPIFOLIA GROWING ON RANGE LAND.

TWO GRASSES GROWING IN THE INCLOSED AREA.

This lupine is an annual plant which grows in the winter rainy season. It is conspicuous in the southern portion of the inclosed area in February and March. In favorable seasons it gives its characteristic blue color to the landscape upon hillsides and bluffs along arroyos. Even this plant is closely grazed by cattle, with, as already stated, apparently no injury. Upon the outside of the area it is grazed as closely as any other forage plant and seems to be as readily destroyed by such grazing as any of the valuable feeds. In the spring of 1908 it was difficult to find any of this plant outside of the fence in localities where it has been very abundant. The rayless golden-rod is the only conspicuous weed not touched by stock.

YIELD OF VEGETATION.

During the time that the area has been under fence an effort has been made to get a quantitative estimate of the amount of herbage produced from year to year. The estimate is based upon measurements of definite plats scattered over the entire field in such a way as judgment dictated would give an average yield. Only the briefest outline of the data secured is given here. The method of measurement is given in Bulletin 67 of this series and need not be repeated here in detail. In general it may be said that the vegetation of plats containing 21 square feet was measured, these plats, eighteen to twenty in number, being scattered over the entire field, as indicated in Bulletin 67. In that publication a more or less detailed discussion is given of methods employed in making these computations, which need not be repeated here. Inasmuch as these are more or less estimates anyway, it is not important that in this paper a slightly different method of computation is used from that in Bulletin 67. The comparisons are not altered.

The results of these measurements are given in the following table:

TABLE I.—*Average yield of forage on plats of 21 square feet each in the fenced area on the Coronado National Forest.*

Year.	Season.	Rainfall.	Seasonal yield.	Annual yield.
		Inches.	*Pounds.*	*Pounds.*
1903	Spring	3.29	520.55	791.02
	Summer	7.48	270.47	
1904	Spring	2.64	14.13	412.45
	Summer	8.24	398.32	
1905	Spring	20.70	799.00	1,174.94
	Summer	6.14	375.94	
1906	Spring	9.88	(a)	(a)
	Summer	3.27		
1907	Spring	7.98	435.88	1,151.76
	Summer	12.03	715.88	
1908	Spring	9.36	300.88	1,225.55
	Summer	10.67	924.67	

[a] No measurements.

In the production of the two crops of feed which we have in the region of the Coronado National Forest two seasons of rainfall contribute. The season which produces the spring crop is much more indefinite than the one producing the summer crop and the crops themselves are very different. The spring feed consists of weedy annuals, and the summer feed of grasses, both annual and perennial.

The winter rainy season, as it is usually called, may begin as early as October and may last through April, or it may be foreshortened at either end and even almost disappear at times. The summer rainy season, on the other hand, is short, commonly better distributed, and occurs in July, August, and September. In the column in Table I showing rainfall, that recorded under the spring season fell between October and April, and that under the summer season in July to September. The rainfall of May and June is negligible and seldom has any influence on feed production.

The rainfall record is taken in the 204-acre pasture shown on the map (fig. 1).

In a general way Table I shows that the yield is dependent upon the quantity of rainfall. Quantity, however, is not the only factor, as will be readily seen. Its distribution is of extreme importance. This feature is not shown in the table. It can be shown only by a detailed account of the precipitation, which it is not considered necessary to publish at this time. The most important point of all brought out by the table is the comparative uniformity of production during the last years and the increase over earlier years. Both of these facts tend to show that the production of the field has been decidedly on the increase and that it may now be at its maximum, which was reached in about three years after its inclosure. Whether the production from now on will be dependent upon rainfall alone remains to be seen, but so far as these records go that is to be expected. It is also to be expected that from now on there will be little, if any, increase in production due entirely to protection. On the other hand, yield alone is only one phase of the improvement which may take place. As pointed out elsewhere, this improvement may be as much a matter of the supplanting of annuals by perennials of greater value as it is of actual number of pounds of feed produced. This improvement, it is believed by the writer, will take place to some extent under future protection, but it is believed that the maximum tonnage has been reached and that future fluctuations will be due in largest measure to variation in rainfall.

The general correlation between the rainfall and the yield of forage is of course very striking, as rainfall is always the most important factor of production here. But the production of 520 pounds of forage on 3.29 inches of rainfall in the spring of 1903 is out of all

FIG. 1.—A BADLY OVERGRAZED AREA IN THE "MACB." PASTURE.

The greater part of the vegetation consists of worthless composites and eriogonums. The latter are fairly good feed. Photographed in September.

FIG. 2.—UPPER PORTION OF THE 590-ACRE PASTURE, SHOWING SPRING VEGETATION UNDER HEAVY GRAZING.

HEAVILY GRAZED PASTURES IN THE SMALLER INCLOSURE.

proportion to the production of only 14 pounds on 2.64 inches in 1904. As a matter of fact nearly 2 inches of the rainfall which produced the spring crop of 1904 fell in the months of October to December. This served to germinate the seed very well, but there was not moisture enough in the spring to make any considerable growth. This is a good illustration of the influence of proper distribution of moisture as well as proper quantity.

CARRYING CAPACITY.

As stated elsewhere, the large field has not yet been pastured, the object thus far being to study recuperation under absolute protection. The only data secured on carrying capacity are from the pastures under private cooperative control contiguous to the upper side of this field. The most satisfactory record, all things considered, is from the "MacB." pasture. (See Pl. V, fig. 1.) The record is short, but even the first year after being inclosed the land improved very perceptibly and still maintained stock at the rate of one head to 20 acres. It should be stated that this pasture is about one-fourth in the oak belt and the remainder in the open grass land immediately below. It is probably the best pasture land in this region. The 204-acre pasture is smaller and less productive by far, mainly on account of thick brush. A long record, reaching over five years, is available for this pasture. Four burros and three horses run short of feed in this pasture occasionally. Of course, the brush interferes with the growth of grass somewhat. On the other hand, the mesquite (*Prosopis velutina*) furnishes some beans, which are a valuable forage. Pasture experiments in the large inclosure were begun in the summer of 1909, and the results will be reported later.

INCREASE OF SHRUBS.

Much has been written about the rapid spread of the mesquite (*Prosopis glandulosa*) and other shrubby vegetation in Texas since the advent of flocks and herds, but the development of this class of plants is so much slower on the inclosed area referred to in this paper that it appears to have been in a large measure overlooked. It is, however, taking place just as surely as in Texas; the only difference is that the growth is much less than half as rapid.

The year previous to the inclosure of the large field a small crop of hay was cut over the best portion of its present area. This, however, was far from any water. Acres were harvested where there was no impediment to the mower. At the present time, six years later, there is not an acre in the whole field where there are no shrubs to interfere with the machine. They are still small, half an inch to an inch in diameter at the base, but large enough to stop a mower.

They have made a very perceptible increase within the writer's acquaintance with the area. The prediction is ventured that the time is coming when these foothill grassy areas, which now have only an occasional small shrub, will be as shrubby as the deserts and lower foothills below them, if not more so.

Some of these shrubs do, of course, furnish some feed, but here, as elsewhere, their growth will be largely at the expense of grasses. For a long time the lower foothills, arroyos, and general desert mesas have been shrubby, and the gently sloping tables between the arroyos and the upper foothills are slowly becoming so.

It will doubtless be impossible to depict all the agencies that are bringing about these changes. It is quite certain that the operations here of the Bureau of Plant Industry have had no influence, for the shrubbery has thickened up on the outside of the inclosure, where the grazing has been very heavy, apparently as much as on the inside. The probability is that neither protection nor heavy grazing has much to do with the increase of shrubs here, but that it is primarily the direct result of the prevention of fires. There never was a time when the shrubby lower foothills and desert mesas produced vegetation enough, except in limited localities, to allow fires to spread, but the grassy foothills, which constitute the upper half of our inclosure, produce sufficient vegetation to burn readily, at least every other year, at the present time. Previously, before the country was stocked, it probably produced more grass than it does now, and was frequently burned over, the fire extending as far down as vegetation would permit. Such burning did comparatively little injury to the grasses, but was very destructive to all small shrubs; consequently, these were able to exist only along the sandy washes, where the grasses were least productive, and upon the lower areas, where fires did not molest them.

Upon the brushy deserts below, the rainfall is so scanty that the grass produced is not sufficient to allow fires to spread. Upon the mountains above, the moist season is more prolonged, the grass remains green longer, and the surface is more broken, often with sheer declivities, which are bare of vegetation, all of which render burning less probable. It must be remembered that frequent burnings are not necessary here to keep down brush. Possibly with comparative freedom from grazing a fire once in ten years would suffice in such an area, because growth is very slow.

The memory of early stockmen is not sufficiently retentive to give us much reliable information regarding the location and density of brush upon these areas when their operations began, so it is necessary to make inferences from changes which are occurring now under the changed conditions. Trained observers have not been sufficiently

FIG. 1.—AN ARROYO PRODUCING BRUSH AND CACTI BUT VERY LITTLE GRASS.

FIG. 2.—FIELD CONTAINING BAILEYA MULTIRADIATA, A CONSPICUOUS PLANT ABOUT THE LOWER BORDER OF THE PERENNIAL-GRASS REGION.

AN ARROYO AND A PERENNIAL-GRASS FIELD IN THE INCLOSED AREA.

long associated with the conditions or interested in this phase of desert vegetation to form from memory accurate judgments.

It is true that the grassy belt is noticeably not continuous in these mountains or elsewhere, but on the other hand, the desert mesquite forest often extends quite to the beginning of the real mountain forest. Such a condition is easily accounted for by local influences. In the canyons the growth of timber is continuous from the mountains to the desert, and in places on the ridges and gently sloping mesas as well (Pl. VI, fig. 1). In both cases the writer believes this condition to be due mainly to the comparatively low fertility of the soil in these situations, assisted in the canyons by the excess of water. The bottoms of the canyons are less productive of grass here to-day than the mesas between, owing to the constant shifting of the sands and the washing off of the finer particles of soil by the frequently changing courses of the flood waters. Action of fires was therefore less pronounced in the canyons, allowing trees and shrubbery to get started, as well as when they did get started, furnishing greater moisture in the subsoil.

The main factor, though, in the opinion of the writer, has been that of fire. It is firmly believed that were it not for the influence of this factor the grassy mesas would to-day be covered with brush and trees, the same as the canyons, except that the growth would be smaller, owing to a more limited supply of moisture. In short, the same laws apply here that govern in our great prairie States (see Pl. VI, fig. 2), where the treeless plains were kept so by frequent fires. It is a very conspicuous fact that the continuance of the desert forest, up to the mountains upon the mesas, occurs where the soil is poorest; in other words, upon the lands which produced least grass, and, consequently, the smallest amount of food for fires. This fact is illustrated in one of the pastures, where there is an area of mesquite upon the gently sloping mesa. But this area is naturally poor soil, and its poverty, on account of location close to the terminus of a temporary stream, has been aggregated for many years by excessive grazing. The same remarks apply to the region just north of Helvetia.

The spread of the seed of the mesquite by cattle and horses eating the beans, thus furnishing a good culture for their development, may have some influence, but it is so seldom that seedlings are met with that it is questionable whether cattle or horses have as much influence as has been suggested. They probably do cause a more thorough and widespread distribution, but probably assist the spread of shrubbery more by eating off the grass, so that there is nothing to burn, than they do by distributing the seeds.

SUMMARY.

The lands under consideration in this paper appear to regain their original productivity in approximately three years of complete protection.

Evidence thus far secured seems to indicate that the best lands in the vicinity will improve under stocking at the rate of one bovine animal to 20 acres. The poorer lands take a correspondingly larger acreage for each animal. The areas that will carry now one head to 20 acres are very limited.

Brush and timber are encroaching upon the grass lands, due, it is believed, to protection from fires.

A ground cover is not a factor below an altitude of about 3,500 feet.

Although the maximum yield of forage may be reached in about three years of protection, improvements in quality of forage will probably go on longer through the continued supplanting of annual plants by perennials of greater value.

Thus far alfilerilla is the only introduced plant which has succeeded, and this only in the most favored situations. It does not appear to thrive in competition with the native perennial grasses at these altitudes when the latter are not grazed.

None of the other two hundred lots of seed sown have given any promise of success except those of three or four native species. These give beneficial results, but the cost is high.

Results seem to be secured much more rapidly by proper protection from overgrazing than by any other method.

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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY—BULLETIN NO. 178.
B. T. GALLOWAY, *Chief of Bureau.*

IMPROVEMENT OF THE WHEAT CROP IN CALIFORNIA.

BY

HENRY F. BLANCHARD,
ASSISTANT AGRONOMIST, OFFICE OF GRAIN INVESTIGATIONS.

ISSUED JUNE 1, 1910.

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1910.

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U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY— BULLETIN NO. 178.
B. T. GALLOWAY, *Chief of Bureau.*

IMPROVEMENT OF THE WHEAT CROP IN CALIFORNIA.

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BY

HENRY F. BLANCHARD,
ASSISTANT AGRONOMIST, OFFICE OF GRAIN INVESTIGATIONS.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., February 28, 1910.

Sir: I have the honor to transmit herewith a paper entitled "Improvement of the Wheat Crop in California," by Mr. Henry F. Blanchard, Assistant Agronomist in the Office of Grain Investigations, and recommend its publication as Bulletin No. 178 of the series of this Bureau.

For many years there has been a steady deterioration in the wheat crop of California, due to two general causes, (1) bad methods in farm practice and (2) a lack of varieties adapted to that region. The Office of Grain Investigations, of this Bureau, has investigated these conditions for about five years, during a part of which time the work has been in cooperation with the state experiment station at Berkeley, Cal. Besides observations on many farms and other investigations, experiments in methods of cultivation and adaptation of varieties have been conducted in detail at two points, Davis and Modesto. The accompanying paper gives briefly some of the results of investigations, to date, along these lines.

Respectfully,

G. H. Powell,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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IMPROVEMENT OF THE WHEAT CROP IN CALIFORNIA.

INTRODUCTION.

An impression exists among many California farmers that the soil will no longer produce profitable yields of good milling wheats. This impression is strengthened by two well-recognized facts: (1) That under past and present methods of wheat culture the soil is failing in many localities to produce as large crops as heretofore, and (2) that the Australian and Club varieties, the most widely grown California wheats, are extremely starchy. As only these very starchy varieties have been extensively grown, it has become necessary for the millers to import large quantities of Turkey wheat from the Middle West to blend with the California wheats.

In order to discover varieties better adapted to California needs than those commonly grown, the Office of Grain Investigations of the Bureau of Plant Industry has for a number of years conducted extensive tests of wheat varieties, including many of foreign origin. In this way it was hoped to improve the California wheat crop in both yield and milling quality. As improved methods of cultivation are necessary also to obtain profitable yields of nitrogenous wheats, an effort has been made to determine the effect of deep plowing and the addition of humus to the soil in the form of winter green-manure crops. The time of plowing, the conservation of moisture, and the eradication of weeds have also been considered. If the State is to continue the profitable use of its grain lands and derive from them the largest possible return, it is quite necessary that there be an improvement in the general practices of cultivation and in the varieties grown.

The investigations covered by this report are in general based upon results obtained and observations made during a number of years, a part of the time in cooperation with the California Agricultural Experiment Station. An effort has been made to so correlate the results and observations that they will be of benefit to the California grain grower in effecting improvement in soil fertility, in the

yield of wheat to the acre, and in the milling quality of the grain produced.

The investigations carried on thus far are simply the foundation for a more extensive work in the future. It is necessary in order to find a few desirable varieties that a large number be first grown in small areas and compared with the commonly grown varieties. The results obtained in this way indicate which varieties may be submitted to practical tests directly with the farmers.

COMMON METHODS OF CULTIVATION UNSATISFACTORY.

The cultivation methods still commonly practiced by many of the farmers of California have been brought about by the conditions existing about 1860, when it was first discovered that wheat could be grown as a profitable crop. These conditions were as follows: Fertile virgin soil, large level valleys facilitating extensive cultivation, a growing season extending from November to June, and a period of rainfall extending over the growing season, with comparatively high temperatures during the winter months and low temperatures during the spring months. The methods are generally very simple and very crude. They consist in the continuous cropping of wheat and barley upon soil which receives only a very shallow cultivation. The farmer is removing the plant food from the soil without the addition of anything to take its place. This is resulting in many localities in a depleted condition of the soil, and profitable crops of wheat are no longer grown.

ORIGINAL METHODS OF CULTIVATION.

The first grain producers of California attempted to crop as large an acreage as possible at a minimum cost. In order to do this, at that time all that was necessary was very shallow plowing (3 or 4 inches in depth), broadcasting the seed, and harrowing it into the soil. This was continued from year to year and fairly good crops were produced for a while. The header and stationary thrasher were used in harvesting the grain. Very little attempt was made on the part of the producer to secure pure seed of the varieties grown or to practice the careful grading of wheat, using only the largest and best kernels for seed. In fact, very little attention was given to the seed used. In many instances the farmer used the poorest grade of grain that he had grown the previous year.

CHANGES FROM ORIGINAL METHODS.

Since the earlier period of wheat production in California some changes have taken place or are now in progress. The most important of these are the replacing of the header and stationary thrasher by

the combined harvester and the beginning of the practice of summer-fallowing the land.

The change to the combined harvester, about 1880, was due largely to labor conditions existing at that time. It was difficult to secure enough men to properly handle the grain, and the methods of harvesting were unsatisfactory. The climatic conditions, as well as the general contour of the land, were found to be favorable to the use of the combined harvester. This machine reduces to the minimum the number of men employed and at the same time utilizes the power of mules and traction engines.

Proper methods of summer-fallowing the land are not yet generally practiced. Summer-fallowing became necessary on account of the foul condition of the soil which had been produced by continuous cropping to wheat. The use of the combined harvester, however, has partly offset the cleaning effect of the fallow. This method of tillage is beneficial, especially when it precedes a particularly dry season, as in this way a large amount of the rainfall for two years is retained in the soil. At first it was found necessary to summer-fallow the land every third year only, but later, every second year.

Other changes which have been taking place during recent years are the reduction in size of a few grain farms and an increase in the depth of plowing on the part of some farmers. These changes, however, occur in individual instances only and are not general in their nature.

BAD RESULTS OF PAST AND PRESENT METHODS.

We now have in many sections of California, as a result of the common methods of wheat culture, a soil which refuses to produce profitable crops of the commonly grown varieties of wheat. The general practice of single cropping has depleted the soil in humus and nitrates and made it very foul with weeds.

Soil Low in Humus and Nitrates.

There are large sections of California which have been sown in wheat and barley under the commonly practiced methods for the past thirty or forty years. These crops rapidly deplete the soil in humus and nitrates. Humus is the decaying organic material which gives body to the soil and is essential in retaining the soil moisture. It also affects the temperature of the soil, producing somewhat higher temperatures in winter and lower temperatures in summer, according to Wollny, as cited by Hilgard.[a] The nitrates of the soil are very essential in the production of wheat, as they form an important part of the necessary plant food. A soil low in nitrates usually tends to

[a] Hilgard, E. W. Soils, 1906, p. 306.

decrease the nitrogen content of wheat grown upon it. On soils low in humus and nitrates there is also a correspondingly low yield of wheat.

Soil Foul with Weeds.

The weed problem is not of minor importance. In fact, when passing through California grain fields and finding that large areas are badly infested with weeds one is impressed with the effect that they must have upon the yields of wheat. This weedy condition is due largely to the common methods of harvesting and cultivating. In many localities the soil has become so weedy that even with the best methods of summer fallowing commonly practiced by the farmer it is impossible to prevent large damage to the crops. The weeds in many instances crowd out the wheat plants by outgrowing them during the winter months.

REQUIREMENTS FOR THE PRODUCTION OF PROFITABLE CROPS.

In order to produce profitable crops of wheat on the worn-out grain lands of California the past and even the present methods of production must in a large measure give way to methods which will produce better results in the future. This to a small degree has already taken place in some sections. There are also large areas of the State upon which wheat has not been grown for as long a period of time as on those sections first farmed. However, these are being rapidly reduced to the same depleted condition on account of the unscientific practices in use.

In some localities where the soil now fails to produce profitable grain crops it has been possible to grow other crops on the same land. In general, such instances are confined to the areas upon which water can be applied. Alfalfa and fruit usually do well in such sections. There are, however, large areas to which water can not be readily applied, and these will no doubt be used for the production of grain for many years to come.

In order to produce crops of grain on such lands it not only becomes necessary to introduce new varieties or improved forms of those now grown, but a change in the actual farming methods for grain as they now exist is absolutely essential. The present methods sufficed for a time, and temporary profits from the soil resulted. It has been comparatively easy to produce crops from a fertile soil without taking into account the effect of such methods upon the soil. It will require much more skill and effort to return the soil to a condition in which good crops of wheat may again be produced.

SMALLER FARMS AND PERSONAL SUPERVISION BY OWNERS.

In the pioneer days of California the interior valleys were not considered of much value for the production of crops on account of

the small amount of rainfall. At that time certain companies were enabled to secure large tracts of this land at a nominal price. These companies discovered that this land would produce good yields of grain and it was cropped on a very large scale. Since that time there has been a gradual breaking up of these large farms into smaller ones. However, there are still too many large ones to make probable the general use of improved methods of grain production. Until the farms are so reduced in size that they may be properly handled we may look for continued low production and further depletion in the soil fertility of the wheat lands.

Another feature of much of the grain production in California is the practice of renting the lands from year to year to men who are not interested in the building up of the soil. The desire of the tenant is to get all that is possible out of the land at the least expense to himself during the time which he holds it. As long as this condition exists there will be a continued decrease in the value of the wheat lands. The remedy for this is the direct supervision by the owner of the methods of cultivation and cropping. He has a real interest in the future condition of his soil and will undoubtedly give it better attention than the tenant who is interested only in the crop he produces each year.

IMPROVED METHODS.

Improvement in the methods of wheat culture is essential to the production of more profitable crops. These improvements include the practice of deeper plowing, the increase of soil humus and nitrates by turning under green-manure crops, and the cleaning of the land of weeds by better methods of cultivation.

Deep Plowing.

At the present time we can not place too much stress upon the importance of deep plowing. The few inches of soil at the surface have been skimmed for so long that they are practically devoid of plant food in available form. For this reason alone it becomes necessary to turn up fresh soil. This will necessitate cutting below that stratum of soil commonly known as the "plow pan," which has been formed by the practice of plowing year after year at the same depth. In many localities plowing at a depth of from 8 to 12 inches is advisable. Unless green-manure crops are to be turned under, this depth should be reached by a gradual increase in depth for two or three years. By this gradual increase in depth the subsoil will become properly mixed with the surface soil.

Deep plowing requires more power than is needed for the ordinary method, and the first deep plowing is more difficult than subsequent

plowings. This is due largely to a more or less packed condition of the subsoil. Deep plowing should be done in the early spring while there is still sufficient moisture in the soil. It should not be done while the soil is either too wet or too dry. While the benefits derived from deep plowing may not be so evident the first season, the results obtained are of permanent character. The subsoil is benefited by direct contact with the air and other climatic influences, and the effects of deep plowing will be more noticeable the second and succeeding years.

FIG. 1.—Wheat plants from six plats treated differently, showing comparative development: *A*, From plat continuously seeded to wheat; *B*, from plat barefallowed in 1908; *C*, from plat upon which horse beans were grown and plowed under in 1908; *D*, from plat upon which Canadian field peas were grown and plowed under in 1908; *E*, from plat upon which rye and vetch were grown and plowed under in 1908; *F*, from plat upon which rye was grown and plowed under in 1908.

ADDITION OF HUMUS AND NITROGEN TO THE SOIL.

As already stated the soil of California grain lands is low in humus. In order to add humus to the soil green-manure crops must be grown and plowed under. This is necessary not only in order that land very low in humus be again placed in good condition, but also that lands in which humus is now fairly plentiful be retained in good shape (fig. 1). Owing to a tendency of very light sandy soil to shift during heavy winds, deep plowing may be detrimental at first on such soils. This soil shifting may, however, be reduced to a minimum by the addition of humus, which will give it body and make possible the practice of deep plowing without injury.

CROPS TO BE USED AS GREEN MANURE.

Canadian field peas and Abruzzes rye do very well as green-manure crops in the valley sections of the State. Under favorable conditions in the Sacramento Valley peas alone have given very good results when seeded at the rate of 80 pounds to the acre. On the lighter soils of the San Joaquin Valley peas do not make as rank a growth as in the Sacramento Valley. For this reason it is suggested that peas and rye be grown together, the rye to be sown at the rate of 40 pounds and the peas 50 pounds to the acre. The rye and pea vines will add humus to the soil, while the nodules on the roots of

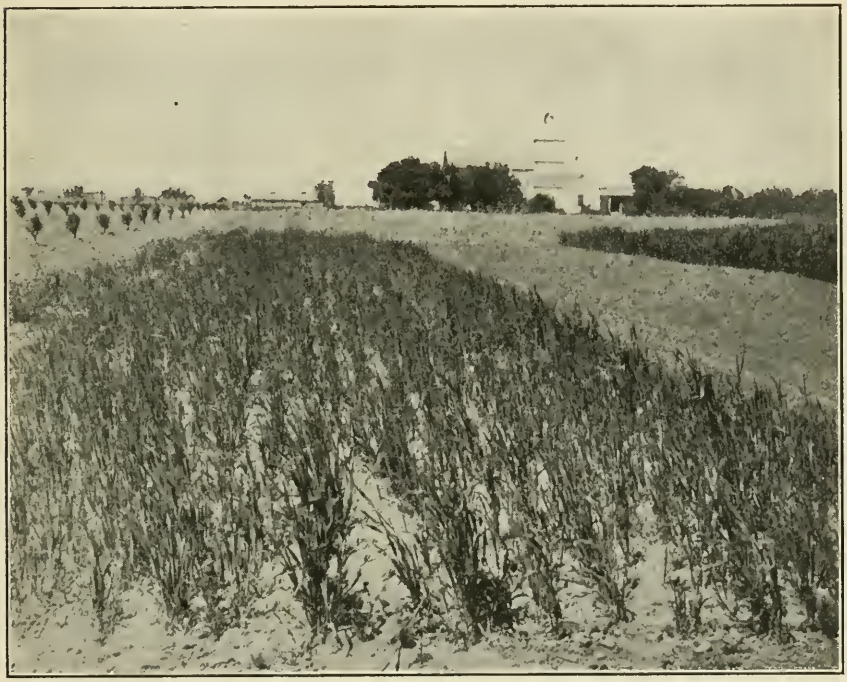

FIG. 2.—Wheat growing on plat which has been continuously seeded to the same crop. (See figure 1, *A*.)

the pea vines will transfer the nitrogen of the air to the soil in the form of nitrates. If rye and peas are to be grown separately, the rye should be sown at the rate of 70 pounds and the peas at the rate of 80 pounds to the acre.

TIME AND METHOD OF HANDLING.

Rye and peas for green manure must be grown as a winter crop. They should be planted as soon as it is possible to plow the land in the fall and should be turned under before the land is too dry for plowing in the spring. Usually there is sufficient moisture in the

soil to allow the planting of green-manure crops by December 1, though in some sections and in exceptional seasons the planting may be necessarily later. It is not advisable, however, to sow later than December 15, for unless the early spring rains are so delayed as to facilitate late plowing the green-manure crop will not be of much value. This crop should be turned under during early March before the soil is too dry for deep plowing. In other words, in order to give green-manure crops the maximum period of growth it is necessary to sow as early as the ground can be worked in the fall and to turn under as late as possible in the spring.

The length of the growing period is regulated very largely by the

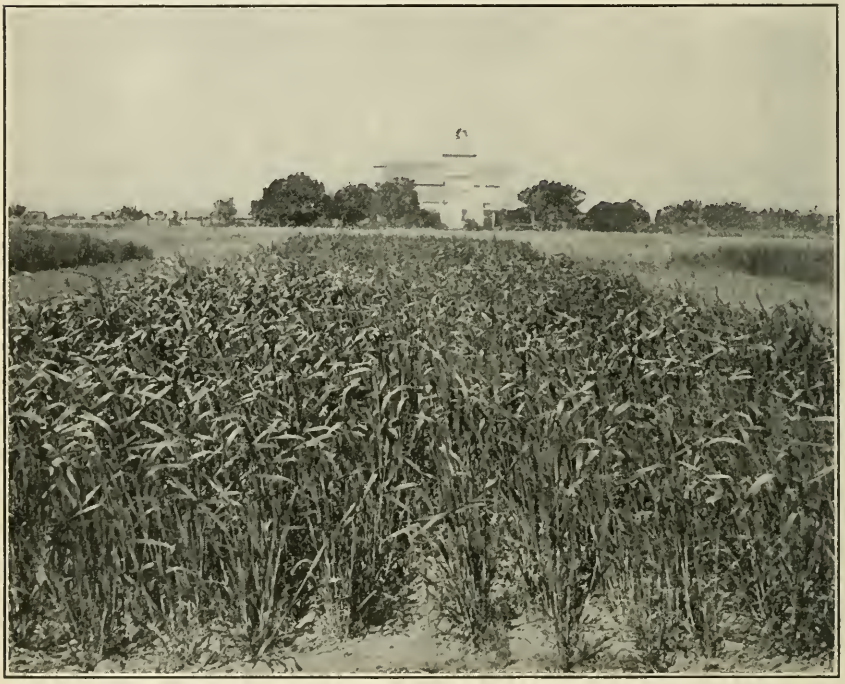

FIG. 3.—Wheat growing on plat on which Canadian field peas were grown and plowed under in 1908. (See figure 1, *D*.)

length of the rainy season. The dry condition of the wheat fields in the fall permits a plowing of only 4 to 5 inches in depth when getting the stubble land in shape for the early planting of green-manure crops. The stubble should be double-disked, where possible, immediately after the wheat crop is harvested. The disking prepares the land to retain the moisture already present and to receive the light precipitation coming during the fall months, thus putting it in shape for an early shallow plowing and a good seed bed. In the spring the land should be plowed deep in order to get

the growing peas or rye well under, where they will readily decay, after which the soil should be well harrowed immediately.

Effect of Deep Plowing and Green Manuring.

The effect of deep plowing and green-manure crops upon the yield of wheat, as determined by observation and actual experiment (see figs. 2, 3, 4, and 5), is shown in Table I, these yields being obtained at Modesto, Cal., in 1909.

INCREASED YIELDS.

While the results indicated are not entirely conclusive, for the reason that they are not based upon trials extending over a long

Fig. 4.—Wheat growing on plat on which rye and vetch were grown and plowed under in 1908. (See figure 1, *E*.)

series of years, they give an idea of what may be accomplished by the deep plowing under of green-manure crops. As indicated, horse beans used as green manure appear to give better results than peas. However, they have a very thick and heavy stalk, and an enormous quantity of seed is required on account of their habit of growing a single stalk from each seed. They are not recommended in the place of peas, which will give better results in combination with rye as a green-manure crop.

TABLE I.—*Effect of deep plowing and green-manure crops on the yield of wheat at Modesto, Cal., 1909.*

No. of plat.	Preceding treatment or crop.	Yield per acre.	Weight per bushel.
		Bushels.	*Pounds.*
1	Fallow	28.00	61
2	Horse beans (turned under)	35.33	61
3	Canadian field peas (turned under)	33.66	60
4	Wheat (26 bushels)	15.66	60
5	Rye and vetch (turned under)	50.66	60
6	Rye (turned under)	51.33	61

The cultivation of the plats indicated in the table was as follows: In the fall of 1907 all of the plats were laid out on summer-fallow

FIG. 5.—Wheat growing on plat on which rye was grown and plowed under in 1908. (See figure 1, *F*.)

land and all were plowed to a depth of 6 inches and harrowed. Plat 1 was allowed to remain fallow. Plat 4 was sown to wheat. Plats 2, 3, 5, and 6 were sown, as indicated, to horse beans, Canadian field peas, rye and vetch, and rye alone. The vetch in plat 5 made a very poor stand, while the horse beans and peas made a fairly good stand. The stand of rye was excellent.

In March, 1908, plats 1, 2, 3, 5, and 6 were plowed 8 inches deep, harrowed, and kept clean throughout the summer and fall. Plat 4,

which yielded at the rate of 26 bushels of wheat to the acre, was double-disked immediately after the wheat was taken off.

The first of December, 1908, all plats were plowed to a depth of 5 inches and sown to wheat. The resulting yields are given in Table I. In two years' time the plat continuously seeded to wheat has produced 41 bushels of wheat. However, the first year's yield, 26 bushels, was produced after summer fallow and the second year's yield, 15.66 bushels, shows a decrease of nearly half. It is quite probable that the third year will give a very low yield and that in a series of five years the quantity of wheat produced from continuously seeded plats would be much smaller than from the other methods of cultivation.

It follows, then, from this experiment, that deeply plowed summer fallow will give much better yields than shallow-plowed, continuously cropped land. Plats 1, 2, 3, 5, and 6 were all plowed at the same depth, and the last four were fallowed also after turning under the green crops. The yields indicate that the addition of organic matter (humus) to the soil is beneficial in increasing the production of crops and that this increase is proportional to the quantity rather than the quality or kind of organic matter added.

INCREASED PROFITS.

The yields shown in Table I were obtained in plat work, where the varieties received the best possible attention, thus giving higher yields than would have been probable under field practice. In our estimate of the increase in profits brought about by thorough methods of cultivation, the yields are estimated at two-thirds the value given in the table.

The estimate made of increase in net profits is based largely upon observation of the general cost of farm work in the State. It may not be absolutely accurate in every particular, but it serves well in bringing out a comparison of the common methods of cultivation employed with the more intensive methods suggested in this paper.

Approximate cost of cultivation per acre by the common method.

First plowing (5 inches deep)	$1.25
Second plowing (5 inches deep)	1.25
Two harrowings	.20
	2.70

Approximate cost of cultivation per acre by the improved method.

Double-disking stubble	$0.50
First plowing (5 inches deep)	1.25
Second plowing (8 inches deep)	2.00
Third plowing (4 inches deep)	1.25
Three harrowings	.30
Rye seed for green manure	2.00
	7.30

The approximate cost of cultivation by the common method is $2.70 per acre, as compared with $7.30 per acre by the improved method suggested, which gives an increased cost of $4.60 per acre for better tillage. As shown in Table I, we have almost doubled the yield per acre by the improved methods. Suppose the yields given in the table were reduced to two-thirds their value, as previously suggested. We still have wheat, following ordinary methods of bare fallow, yielding at the rate of 19 bushels per acre, while wheat following deep plowing and rye as a green-manure crop yields at the rate of 34 bushels per acre. With wheat at $1 a bushel we have at a cost of $2.70 per acre produced $19 (not deducting cost of harvest, etc.). By better methods at a cost of $7.30 per acre we have produced $34 (not deducting cost of harvest, etc.). This gives an approximate increase of net profit of $10.40 per acre in favor of the better method of tillage.

Cleaning the Land of Weeds.

The problem of cleaning the land of weeds reduces itself to systematic cultivation and the production of rapidly growing varieties, especially as concerns their early development. Where cultivated crops are grown it is readily understood that the problem of getting rid of weeds is not so difficult as with wheat crops. Results obtained lead us to suggest that the following method of cultivation, if rigidly enforced, will help in a large measure to reduce the weeds in wheat fields:

(1) Thoroughly double-disk the land as soon as possible after harvest, thus stirring the surface, breaking up the stubble, and covering the weed seeds. Then allow the land to stand until the weed seeds at the surface have had a chance to germinate after the first rains.

(2) As soon as the weed seeds are well germinated, plow the land to a depth of 4 or 5 inches and harrow well. This should be done, if possible, not later than December 15.

(3) Between March 1 and 15, plow to a depth of from 8 to 12 inches. This exposes the weed seeds not turned up by the first plowing. Harrow the surface thoroughly immediately after plowing. Whether a summer crop is grown or the land is allowed to lie fallow it should be kept well cultivated and free from weeds.

(4) In November, plow to a depth of from 4 to 5 inches and sow the wheat about 2 inches deep.

(5) Just before the grain appears through the surface the land should be thoroughly double-harrowed in order to kill all weeds which have germinated following the seeding of the wheat.

(6) The variety of wheat grown should make a rapid, erect, early growth in order that it may keep ahead of and choke out all the young weeds which are not killed by the final harrowing. (Our

investigations tend to prove that the flat-growing types of true winter wheat will not succeed in the valley soils of California, especially in their present condition of weediness.)

(7) The young grain should be thoroughly harrowed as soon as the ground is dry enough in the early spring, thus covering all of the young weeds which have started during the rainy season.

DEVELOPMENT OF BETTER VARIETIES OF WHEAT.

The proper cultivation of the soil is essential to the production of good yields of all varieties of wheat. It does not follow, however, that every variety of wheat will give good yields even on fertile soil properly cultivated. This erroneous idea prevails among certain grain growers. The United States Department of Agriculture has tested hundreds of varieties of wheat in different sections of the country and has found that comparatively few of these varieties are adapted to the prevailing climatic and soil conditions of each section. Varieties which produce good yields in one section of the country are found to be absolute failures in other sections.

Variety Tests in California.

Although a large number of varieties of wheat have been tested in California by this Department during the past five years, very few of these are adapted to the climatic and soil conditions of this State. California presents such a variety of climates that a type of wheat which may give excellent results in one section of the State does poorly in another. Our investigations thus far are not of long enough duration to enable us to state definitely the variety of wheat best adapted to any particular locality of the State. However, the results indicate that for the localities in which tests have been made we have now varieties which are better adapted to the prevailing conditions than those commonly grown by the farmers. We are able, therefore, with a fair degree of certainty, to recommend varieties for a large portion of the State.

Table II presents a list of some of the varieties of wheat which have been grown in California in connection with the investigations of the Department. The average yields to the acre, the number of days required to reach maturity, and the fruiting period (the number of days between the time of blossoming and the time of ripening) are based upon the plat experiments continued for three years in the San Joaquin Valley. The results obtained from the same varieties when grown in the Sacramento Valley compare very favorably with those indicated in this table. A few of these varieties are proving to be well adapted to both the localities in which they have been grown.

TABLE II.—*Results of variety tests of wheat in the San Joaquin Valley, California.*

Grain Investigations No.	Variety.	Manner of early growth.	Average number of days maturing.	Average number of days in fruiting period.	Quality of grain.	Nonshattering character.	Average rate of yield per acre.	Weight per bushel, 1909.
							Bushels.	*Pounds.*
1698	Allora	Erect	180	45	Starchy	Good	38.08	61
3019	Australian	Semi-erect	194	38	do	Fairly good.	35.96	61
2511-2	Blé Noir	do	161	39	Medium starchy.	do	48.11	58
2921	Bolo Blanco	Erect	191	46	Starchy	Good	58.39	62
2986	California Gem.	Semi-erect	198	38	do	Fair	29.78	61
2210	Cap Sheaf	Spreading.	189	38	do	do	32.49	60
2227	Chul	Erect	187	41	Glutinous, spotted.	Very good	44.56	63
3018	Club	do	165	41	Starchy	Good	13.98	59
1437	Crimean	Spreading.	199	35	do	Fairly good.	26.55	63
2988	Dietz Amber	do	194	37	do	Fair	25.68	62
1697	Early Baart	Erect	162	38	do	Fairly good.	24.61	63
2397	Erivan	do	192	35	Glutinous, spotted.	Good	39.74	61
1596	Fretes	Semi-erect	193	42	Medium starchy.	Fairly good.	46.49	63
2398	Galgalos	Spreading.	191	37	do	Good	34.94	61
1442	Kharkof	do	193	29	Starchy	Fairly good.	38.66	62
2246	Kubanka	Erect	170	36	Glutinous, spotted.	Very good	18.82	63
1593	Marouani	do	185	40	do	do	24.82	62
2235	do	do	184	38	do	do	39.99	62
1597	Medeah	do	196	42	do	do	23.03	62
2989	Minnesota No. 66.	Spreading.	203	36	Medium starchy.	Fair	29.00	61
2873	Minnesota No. 163.	do	202	35	do	do	19.71	60
2888	Filipino	Erect	195	38	Very starchy	Very good	29.41	60
1970	Propo	Semi-erect	192	42	Starchy	Fairly good.	41.18	63
2991	Purple Straw	do	182	35	do	Fair	44.99	60
2984	Saumur de Mars.	do	190	37	do	Poor	50.92	60
2983	Chiddam	do	191	38	do	do	51.66	61
2235-1	Selection from Marouani.	Erect	178	41	Glutinous, spotted.	Very good	53.76	63
2899	Selection from Chul.	do	152	36	do	do	45.33	62
1743	Sonora	do	186	44	Starchy	Fairly good.	34.77	64
1561	Theiss	Spreading.	201	36	do	do	19.68	63
1558	Turkey	do	199	39	do	do	32.11	63
2247	Velvet Don	Erect	185	38	Glutinous, spotted.	Very good	23.53	63
2985	Washington Bluestem.	Semi-erect	170	36	Starchy	Fairly good.	24.29	61
2404	Yantagbay	Erect	184	37	Glutinous, spotted.	Very good	57.28	64
2096	Yellow Ghar-nowka.	do	185	39	do	do	24.90	63
2592	[Unnamed]	Spreading.	193	40	Starchy	Fairly good.	41.99	63

SELECTING VARIETIES FOR CALIFORNIA.

In selecting a variety of wheat which is better adapted to California conditions than the commonly grown varieties a number of matters must be taken into consideration.

CLIMATE AND SOIL.

The climate and soil of the locality in the State where the variety is to be tested are both important factors limiting the distribution of a variety. Some varieties will do well on light soils with a small amount of precipitation, while other varieties require a heavier soil with a larger amount of moisture.

HABIT OF GROWTH.

The effect of the character of the early growth of a variety on its struggle with weeds is very important. (Figs. 6 and 7.) In the valley sections of California, where the temperature does not fall much below freezing during the winter months, varieties of vigorous, upright growth are needed in order that they may keep ahead of and choke out the weeds that start at this time. Varieties with a spreading habit of early growth may be adapted to mountain sections of high elevation, where there is a good deal of snow during the winter months and the temperature falls considerably below the freezing point, thus preventing weed growth until spring.

FIG. 6.—Representative plants of six varieties of wheat from uniform plats planted November 21, 1908, at Modesto, Cal., showing their comparative development on May 1, 1909: 1596, Fretes; 1698, Allora; 2397, Erivan; 3019, Australian; 2227, Chul; 1558, Turkey.

NONSHATTERING HABIT.

The nonshattering character of the head of wheat is a very important factor in some sections of California, as heavy windstorms often occur after the grain is ripe and before it is harvested. These winds shatter out a great deal of grain from varieties which have not a very close-fitting chaff. The method of harvesting also has a tendency to shatter out much of the grain where it is not closely held by the chaff, owing to the fact that the crop is often allowed to stand for weeks after it is ripe.

MILLING QUALITY.

The milling quality is perhaps the most important factor to be considered in California. On account of the poor quality of the commonly grown varieties the California millers are unable to make good flour from these wheats when using them alone. Better milling wheat is imported from Kansas and other States of the Middle West to blend with California wheat in the production of flour. From one-third to one-half of the blended wheat is made up of the Turkey variety. It is desired to make unnecessary this importation by the production in California of varieties equally as good. The flour value of wheat is judged by both the quantity and the quality of the product. In order to produce wheat of superior milling quality it is essential that varieties be grown which will give more and better protein to the acre. The quality of the protein depends on the quality of the gluten.

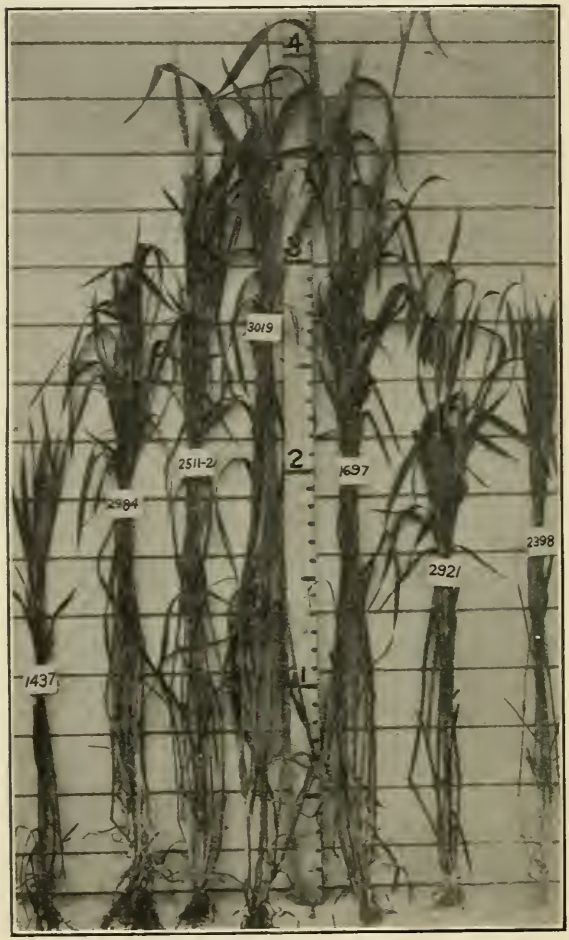

FIG. 7.—Representative plants of six additional varieties of wheat from uniform plats planted November 21, 1908, at Modesto, Cal., showing their comparative development on May 1, 1909: 1437, Crimean; 2984, Saumur de Mars; 2511-2, Abyssinian; 3019, Australian; 1697, Early Baart; 2921, Bolo Blanco; 2398, Galgalos.

OTHER REQUISITES.

The ability of a variety to yield well under proper environment, the possession of a stiff or a weak straw, and the presence or absence of beards are all factors that need no further explanation, but must all be considered in the selection of a variety. Rust resistance is an important factor, especially in the coastal sections of California. Beardless varieties are often desired by the grower, as he may wish, on account of

occasional seasonal disadvantages, to cut the crop for hay instead of allowing it to stand for grain. In such a case beardless wheats may be of more value than bearded ones, though this is not an important matter.

Seed Improvement by the Grower.

It is very important that the grain growers of California practice better methods of seed selection.

SMALL COMPARED WITH LARGE SEED.

The idea which prevails among some growers that small, light seed will produce as good crops as large, heavy seed is erroneous. In some instances, under very favorable conditions and if sown at the same rate to the acre according to weight, the small, light grains produce as heavy yields as the large, heavy grains, but the grain is of an inferior grade. The reason for the equality in yield to the acre is largely due to the fact that in the case of the seeding of small, light grains there are many more plants to a given area than when it is seeded with an equal weight of large, heavy grains of the same variety.

Heavy, plump grain produces stronger and more vigorous plants than light, shriveled grain. The reason for this is that the plump grain contains a larger amount of food for the very young plant. The light, shriveled grain produces weak plants. This is a fact well understood by all who are endeavoring to improve their crops by careful and practical selection of seed.

It behooves the grain grower, then, to have at his disposal a good fanning mill with which he can grade his seed, blowing out all light, shriveled grain and separating the large grains from the small. Another advantage in the use of the fanning mill is the separation of the weed seed from the wheat.

THE SEED PLAT.

A practical method of improvement of seed, which should be used by every wheat producer in California, is what is known as the seed plat. This method is simple and easily applied. First, select from the general field at ripening time a large quantity of good heads of a single desirable form. Only heads from the best plants should be selected, and they should be from places where the soil is uniform with other parts of the field and not from an especially fertile spot or at the edge of the field. The heads should be thrashed by hand and the seed sown on well-prepared land free from volunteer grain. This crop should be harvested and thrashed separately from the main crop, care being taken that the machinery used is free from all other grains which might cause a mixture. The first portion thrashed should be rejected, as it is most likely to contain such a mixture. The grain from the seed plat should be used, as far as it will go, for the general crop the succeeding year. If there is a considerable acreage it may be necessary to continue the seed plat for a second year in order to obtain sufficient seed for the main crop. In order to effect permanent improvement the grower should make these

selections of the best heads every year and sow them on the seed plat as suggested.

TWO NEW VARIETIES OF WHEAT ADAPTED TO CALIFORNIA CONDITIONS.

Of the many new varieties of wheat tested for yield and nitrogen content, the Chul (G. I. No. 2227) and the Fretes (G. I. No. 1596) have proved superior to the White Australian and Club varieties grown in the San Joaquin and Sacramento valleys and are recommended for trial by farmers.

THE CHUL VARIETY.

Origin and History.[a]

Chul wheat (fig. 8) was received by the Office of Seed and Plant Introduction, December 1, 1902, from Dzhizak, a town about 100

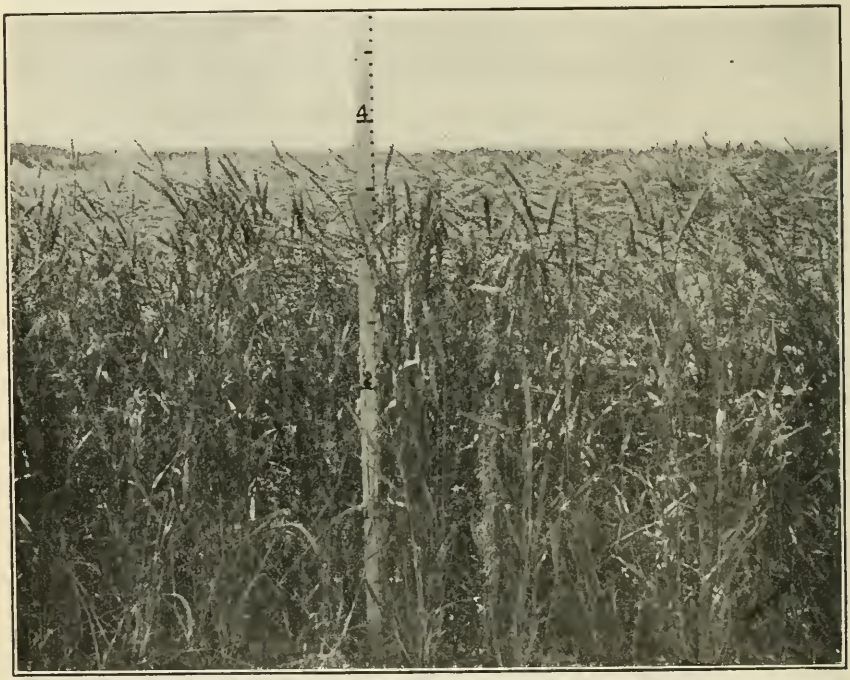

Fig. 8.—Chul wheat (G. I. No. 2227) growing at Modesto, Cal., in 1909. Yield to the acre, 53.33 bushels.

miles north of Samarkand, Turkestan. It was obtained through the Samarkand representatives of Mr. H. W. Durrschmidt by Mr. E. A. Bessey, of the Bureau of Plant Industry, August 30, 1902. The following notes concerning it were secured by Mr. Bessey:

Chul is grown on the steppes of Russia without irrigation. The grains are hard, but it is not a durum wheat. This variety yields two harvests a year, for it can be

[a] Bulletin 66, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1905, p. 250.

sown as either a winter or spring wheat. If the former, the harvest comes in July; if the latter, the harvest comes in September. If sown in the spring, it is sown just as soon as the snow melts. The spring sowing is most certain to yield a good crop, for the fall sowing must depend upon the rather uncertain snows. This seed, however, is from the fall-sown seed. It is selected from over 1,000 poods offered for sale, and is remarkably clean and free from foreign seeds for this region.

Introduction into California.

Seed of Chul wheat was first distributed by the United States Department of Agriculture in 1903 to a few farmers in California. Since 1903 small quantities have been sent out from time to time for the purpose of testing its adaptability. In 1904 and 1905 a variety test was commenced in Stanislaus and Sutter counties. This test was in direct charge of an officer of the Department, and has continued up to the present time. A limited distribution of improved seed of California-grown Chul wheat has been made to reliable farmers who are desirous of improving the yield and quality of their crop.

Description.

The Chul is an early, erect, and vigorous variety which may be sown as late as February 15 and mature a good crop. It grows to a height of from 2½ to 4 feet and stools freely. The heads are medium long, tapering, and bearded. This variety has a very close-fitting chaff and does not shatter readily. As originally introduced it contained two forms, the one having white chaff, while the other produces red chaff. The kernels are large, long, and translucent in character. They are harder and more glutinous than those of the White Australian wheat. As originally introduced there were also two types of kernels, the one type being amber in color, the other dark red or reddish amber.

A separation of the red chaff form was made in 1905 at the Department's Plant Introduction Garden at Chico, Cal. Since that time the Department has separated the two forms represented by both colors in the original seed. This has been done by starting with single plants which were each characteristic of the form desired.

Yields Obtained.

Very promising results have been reported from California to this Department by farmers who have given Chul wheat a trial. In variety tests made by the Department it has made a very favorable showing, excelling the commonly grown varieties in yield to the acre in some sections of the State.

The average yield to the acre of Chul wheat for 1907, 1908, and 1909, as compared with the White Australian, is as follows:

Chul (G. I. No. 2227)	44.5 bushels.
Australian (G. I. No. 3019)	35.9 bushels.

Milling Quality.

The milling quality of Chul wheat is superior to that of either the Club or the White Australian wheat, and for this reason this variety is of much value to the State of California. As previously shown, the common California wheats do not in themselves produce a high grade of flour.

The Department has made milling and baking tests of Chul and White Australian wheats grown at Modesto, Cal., in 1908. The results of this test indicate that Chul wheat produces from 100 pounds of grain about 10 pounds more flour than the Australian, and that it mills very much like Turkey wheat. The flour from the Chul is darker than that from either Australian or Fretes wheat, which in itself indicates that the Chul variety is stronger in gluten.

In the baking test Chul flour required more water to the loaf than that of the Australian variety and produced loaves of fair color and texture.

In August, 1909, the Oakdale Milling Company, Oakdale, Cal., made a milling test of Chul wheat, crop of 1909, grown at Modesto, Cal. This test gave 55 per cent wet gluten for the Chul, while similar tests showed only 10 to 38 per cent in the White Australian. Mr. Haslacher, manager of this company, was very enthusiastic over this variety and anxious that farmers should secure seed.

THE FRETES VARIETY.

Origin and History.[a]

Seed of Fretes wheat (fig. 9) was received by the Office of Seed and Plant Introduction of the United States Department of Agriculture on September 26, 1901, from El-Outaya, Constantine, Algeria. It was obtained by Messrs. D. G. Fairchild and C. S. Scofield, who make the following notes on it:

> This variety, sometimes called Freitiss, is one of the few soft wheats grown in Algeria. It is particularly noted for its early maturity and is often extensively planted in the Sahara Desert in seasons when the winter rains occur so late that the durum varieties usually grown would not have time to mature. When planted in November, as it is in Algeria, at the same time with durum varieties, it is said to ripen two months in advance of them. The seed obtained was grown on the rather salty desert sands in the vicinity of El-Outaya, north of Biskra, and watered with somewhat alkaline but still drinkable irrigation water. The variety is said to have originated from a shipment of Russian wheat which was made into Algeria at the time of a famine many years ago. Its early-maturing qualities attracted attention, and it has been cultivated in small quantities by the Arabs ever since. The seed obtained is from the farm of Mr. Charles B. des Places.

[a] Bulletin 66, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1905, p. 151.

Description.

Fretes wheat is an early, erect, vigorous variety and should be sown not later than December 15. It grows to a height of from 3 to 4½ feet and stools well. The heads are of medium length, tapering, and bearded, with white chaff. The chaff of Fretes wheat does not inclose the grain as closely as that of the Chul variety, but still holds the seed fairly well. The kernels are medium large and plump, of medium length, and a reddish-amber color. They are softer than those of

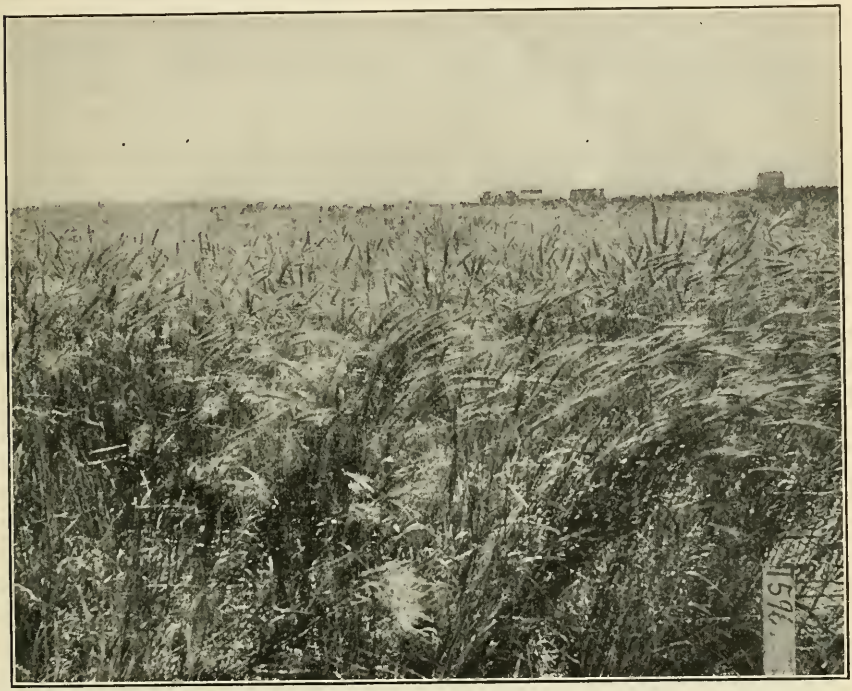

Fig. 9.—Fretes wheat (G. I. No. 1596) growing at Modesto, Cal., in 1909. Yield to the acre, 56 bushels.

Chul wheat. Single-plant selections have been made which are very promising.

Yields Obtained.

Fretes wheat was distributed by the Department to a few farmers in California as early as 1902, and very good reports on its adaptability have been received. In 1904 and 1905 the Department commenced a variety test of this wheat on the experimental grounds in Sutter and Stanislaus counties. The observations made on the adaptability of this wheat to California conditions indicate that it will produce a larger yield to the acre than either the White Australian or Club wheats and that it is superior as a milling wheat.

The average yield to the acre of Fretes wheat at Modesto, Cal., for 1907, 1908, and 1909, as compared with the White Australian (fig. 10), is as follows:

Fretes (G. I. No. 1596)	46.5 bushels.
Australian (G. I. No. 3019)	35.9 bushels.

Milling Quality.

Milling tests of this variety have been made by the United States Department of Agriculture and by the Oakdale Milling Company. As a result of the test of the grain grown in California during 1908, made by the Department's laboratory at Fargo, N. Dak., we find this variety superior to the Club as a flour producer. It is also slightly superior to the White Australian. In this test it was discovered that

Fig. 10.—White Australian wheat (G. I. No. 3019) growing at Modesto, Cal., in 1909. Yield to the acre, 44 bushels.

there was a slight increase in the quantity of flour produced from 100 pounds of the Fretes over that produced from the same quantity of Australian wheat. It milled very much like the Australian. Approximately the same quantity of water was required to produce a loaf of bread made from this flour as from the Australian. The loaves were slightly smaller but heavier than those baked from the Australian. The color and texture were fairly good. As with the Chul wheat, a

milling test of the 1909 crop of the Fretes was made by the Oakdale Milling Company, Oakdale, Cal. This test indicated that the Fretes milled easily. It also possessed a 40 per cent wet-gluten content as compared with the Australian samples received and tested by the company, which contained from 10 to 38 per cent of wet gluten.

PURE SEED OF THE CHUL AND FRETES VARIETIES.

From the foregoing facts there can be little doubt that the improved types of the Chul and Fretes varieties are of great value to California. Much care, however, should be exercised by the growers in securing pure seed.

It is reported that Chul wheat is being grown in quantity by a few farmers in the Sacramento Valley from seed introduced into California by the United States Department of Agriculture in 1903. It is also reported that this wheat is used to good effect in blending with the common wheats in the production of flour. Samples of the 1909 crop, which have been received, show that this wheat is mixed with other varieties. This is probably due to lack of care on the part of growers in keeping the variety pure. This mixture is an inferior grade of seed and is not desirable for the farmer wishing to start with pure seed of the Chul variety.

The Office of Grain Investigations of the Bureau of Plant Industry can usually supply small quantities of pure seed of these and other varieties.

PROTEIN CONTENT AS AFFECTED BY TIME OF SEEDING.

Observations in California indicate that the length of the growing and fruiting periods of a variety of wheat controls, to a considerable degree, the percentage of protein contained. Long growing and fruiting periods produce grains lower in protein content than short growing and fruiting periods. An effort was made during the past year to determine the effect of the length of these periods upon the protein content of the Chul and Fretes varieties sown early and late. The results obtained are given in Table III.

TABLE III.—*Effect of the length of growing and fruiting periods on the protein content of the Chul and Fretes wheat varieties.*

Grain Investigations No.	Variety.	Length of growing period.	Length of fruiting period.	Protein.[a]	Yield to the acre.
		Days.	*Days.*	*Per cent.*	*Bushels.*
2227	Chul	171	46	11.06	53.33
2227	do	151	41	12.43	52.89
1596	Fretes	177	45	10.94	56.00
1596	do	152	40	14.08	45.53

[a] The percentages of protein were obtained by multiplying the percentage of nitrogen by 5.7.

As indicated in Table III, a higher percentage of protein is produced in a short growing and fruiting period than in a long period. The yields of Chul wheat are nearly equal, while there is some difference in those of the Fretes. In order to shorten the periods and produce grain rich in protein, the seeding should be done as late as possible in the fall. The Chul variety is especially adapted to late seeding for the reason that it is a vigorous grower and ripens early. Excellent results have been obtained from the Chul when sown as late as February 25, but usually the seeding should be done between November 15 and December 25. The Fretes seed should be in the ground by December 15. The above dates refer to the time of seeding in the San Joaquin Valley. These wheats may be sown a month later in the Sacramento Valley and still give good results under ordinary conditions.

SUMMARY.

Wheat yields in California are low and the quality poor. Experiments have been conducted to discover the causes and remedies. Two remedies are proposed in this bulletin, namely, better cultivation methods and better varieties.

The cultivation methods commonly practiced by the wheat farmers of California are unsatisfactory. They consist in the continuous cropping of wheat and barley upon soil which receives only a very shallow cultivation.

The farmer removes the plant food from the soil without adding anything to take its place. This is resulting in many localities in a depleted condition of the soil and in unprofitable crops.

When wheat was at first produced, good crops were secured by very shallow plowing, broadcasting the seed, and harrowing it into the soil. Very little attempt was made to secure pure seed or to practice the careful grading of wheat.

Some important changes have taken place, among which are (1) the replacing of the header and stationary thrasher by the combined harvester and (2) the practice of summer-fallowing the land. A reduced size of farms and an increased depth of plowing occur in individual instances.

In many sections of the State there has resulted from the original methods a soil depleted in humus and nitrates and foul with weeds, which fails to produce profitable crops. There are three chief requirements in restoring the production of profitable crops. These are (1) smaller farms, personally supervised; (2) improved methods, including deeper plowing, increasing the humus and nitrates of the soil, and cleaning the land of weeds; and (3) the development of better varieties.

Soil humus and nitrates are easily increased by turning under green-manure crops. Crops proving to be of value as green manure are Canadian field peas and Abruzzes rye. Green-manure crops should not be sown later than December 15. The stubble should be double-disked immediately after the wheat crop is harvested, followed by a shallow plowing as early as possible in the fall. These crops should be turned under during early March before the soil is too dry for deep plowing, which is necessary in order to get the growing peas and rye well under, after which the soil should be harrowed immediately.

The good effect of deep plowing and green manuring is proved in actual experiment by increased yields and profits.

A method of cultivation whereby the land may be cleaned of weeds should be employed.

A large number of wheat varieties have been tested in California in an attempt to find better ones. Factors entering into the selection of varieties for California are the climate and soil of the locality where the variety is to be tested, the habit of growth of the variety, its nonshattering character, milling quality, yield, strength of straw, the presence or absence of beards, and rust resistance.

It is important that grain growers practice better methods of seed selection. The seed should be graded with a fanning mill. A practical method of improvement is the use of what is known as the "seed plat."

The Chul and Fretes wheats are new varieties adapted to California conditions. In some sections of the State these wheats have excelled the commonly grown varieties in yield to the acre.

Milling and baking tests of the Chul and Fretes varieties have been made which indicate that they are superior to Australian and Club wheats in these respects.

Much care should be exercised by the growers in securing pure seed of these wheats.

Observations indicate that the length of the growing and fruiting periods of a variety of wheat controls to a considerable degree the percentage of protein contained. Short growing and fruiting periods produce grain with a high percentage of protein.

The Chul and Fretes varieties are adapted to comparatively late seeding, which is favorable to a high percentage of protein in the grain produced.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 179.

B. T. GALLOWAY, *Chief of Bureau.*

THE FLORIDA VELVET BEAN AND RELATED PLANTS.

BY

C. V. PIPER,

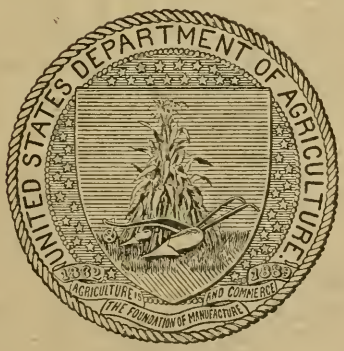
AGROSTOLOGIST IN CHARGE OF FORAGE-CROP INVESTIGATIONS,

AND

S. M. TRACY,

SPECIAL AGENT, FORAGE-CROP INVESTIGATIONS.

ISSUED MAY 19, 1910.



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[Continued on page 3 of cover.]

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B. T. GALLOWAY, *Chief of Bureau.*

THE FLORIDA VELVET BEAN AND RELATED PLANTS.

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C. V. PIPER,

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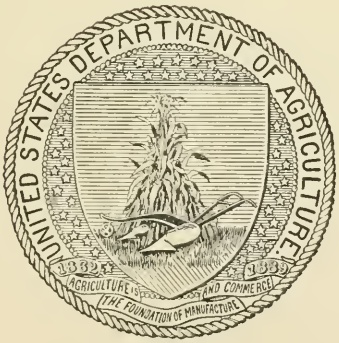

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., February 26, 1910.

Sir: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 179 of the series of this Bureau the accompanying manuscript, entitled "The Florida Velvet Bean and Related Plants," prepared by Messrs. C. V. Piper, Agrostologist in Charge, and S. M. Tracy, Special Agent, Forage-Crop Investigations.

This paper points out an interesting example of the confusion that exists in the botany of the cultivated plants, which has in this particular case brought about the neglect of a number of valuable sorts related to the Florida velvet bean. Two of these species possess decided elements of superiority and will without doubt result in extending far to the northward the culture of this crop, as well as in greatly increasing its importance. This paper discusses nine of the species that have been studied, but is to be considered a preliminary rather than an exhaustive publication.

The authors desire to acknowledge the helpful suggestions and assistance rendered them by Mr. W. F. Wight, Botanist, of this Bureau.

Respectfully,

G. H. Powell,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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B. P. I.—558.

THE FLORIDA VELVET BEAN AND RELATED PLANTS.

INTRODUCTION.

For about fifty years the Florida velvet bean has been known in Florida, and in the last twenty years has become of increasing agricultural importance. Its early history has been told by Mrs. K. S. Bort in Bulletin No. 141, Part III, of the Bureau of Plant Industry.

The Florida velvet bean is principally grown on account of its extreme vigor and the large quantity of pods which it produces per acre. The plants are nearly always utilized by pasturing to stock, cattle being turned into the fields in November and finishing on the velvet bean in good condition for marketing.

The Florida velvet bean is a long-season crop, and even in Florida has to be planted early in the spring in order to mature its seed. On this account an earlier variety has long been a desideratum, especially if along with earliness can be secured a greater production of seed per acre. For various reasons the fact that there are other kinds of Stizolobium closely related to the Florida velvet bean has been overlooked by American agronomists, though at least three such species from India and Java were long ago described. Apparently none of these, however, were introduced for trial in Florida until 1907.

In September, 1906, there were received from Dr. J. W. Hart, Piracicaba, Brazil, seeds of a species of Stizolobium (S. P. I. No. 19181) which differed from the Florida velvet bean in having coal-black, shining seeds, and in February, 1907, another species, with white seeds, was received from Mr. W. S. Lyon, Manila, P. I., under the name of *Mucuna lyonii* Merrill. These two lots were grown in 1907 and since. After their receipt it seemed to be wise to endeavor to get together all of the other species of this genus in the hope of finding varieties that would prove earlier or otherwise more valuable than the Florida velvet bean. In the three years during which this effort has been made, with the assistance of the Office of Foreign Seed and Plant Introduction, twenty sorts distinct at least as to seed characters have been obtained. Not only have these varieties indicated that there are greater possibilities in this group of plants than had been supposed, but an exceed-

ingly interesting botanical problem has been disclosed, as there are clearly more species than had been recognized by botanists.

Until the publication of the paper previously mentioned,[a] the Florida velvet bean had been known in this country under the name of *Mucuna utilis*. Mrs. Bort showed clearly that it could not be the plant originally described under that name, nor could it be identified with any other described species. On this account she named and described the plant as a new species, *Stizolobium deeringianum*. She also emphasized the fact that the Florida velvet bean and allied plants constitute a distinct genus from Mucuna, pointing out that the genus Mucuna consists of perennial plants with woody stems and with a band-like hilum that extends two-thirds of the way around the seed, or more, while the genus Stizolobium[b] consists of plants essentially annual, with an oblong-crateriform hilum to the seed. She further stated that Mucuna in germination is hypogeous, while Stizolobium is epigeous. This last statement is incorrect, as both are hypogeous. There is a pronounced difference, however, in the germination. In Stizolobium the first leaves above the cotyledons are a pair of petioled leaves having solitary cordate leaflets, which immediately are followed by the typical alternate, trifoliate leaves of the plant. In Mucuna, on the contrary, the initial leaves are all alternate, very much reduced, and scale-like. These differences are well shown in Plate I, where the germination of *Mucuna keyensis* is contrasted with that of *Stizolobium hassjoo*.

Of the 20 forms of Stizolobium obtained, 10 have been grown to maturity for one year or more in the field, and several others in the greenhouse. The field work has been conducted principally at Biloxi, Miss., and in cooperation with the Florida Agricultural Experiment Station at Gainesville, Fla. In addition, large quantities of seeds of the Lyon bean (S. P. I. No. 19979) and considerable quantities of the fleshy-pod bean (S. P. I. No. 21094) and of the Mauritius or Bengal bean (S. P. I. No. 21300) have been distributed for field testing.

The characters by which the different species of Stizolobium are distinguished are principally in the pods and seeds; otherwise the species are much alike both in habit and foliage. Slight differences occur in the leaves and flowers, which, however, are not conspicuous. It is probably due to the fact that most herbarium material does not contain mature pods that the distinctness of the species has not before

[a] Bulletin 141, pt. 3, Bureau of Plant Industry, 1909.

[b] The genus Stizolobium was first published by Patrick Browne (The Civil and Natural History of Jamaica, 1756, p. 290) and based upon the species now known as *Stizolobium pruriens*, the common cowitch. The seed characters by which Stizolobium is distinguished from Mucuna have been clearly pointed out by Prain (Journal of the Asiatic Society of Bengal, n. s., vol. 66, 1897, p. 404.)

SEEDLINGS OF MUCUNA KEYENSIS AND STIZOLOBIUM HASSJOO.

A, Seedling of Mucuna keyensis, S. P. I. No. 24427.
B, Seedling of Stizolobium hassjoo, S. P. I. No. 25254.
(Natural size.)

been recognized by botanists. There is also a considerable range as respects the life period of the species, some being much earlier than the Florida velvet bean and others much later.

The pod differences are displayed in differences of size, of shape, of ridges on the valves, and especially in the character of the pubescence. The latter character in the various forms is such that it seems impossible to refer them to a single species, as in no genus of legumes known to us do we find differences of this kind in agricultural varieties known to be such. Furthermore, these plants never seem to have been cultivated sufficiently to give rise to series of varieties such as are found in most cultivated legumes. A number of the species have been cultivated to a slight extent by the Hindus. Another species, *Stizolobium velutinum* (Hassk.) (*Mucuna velutina* Hassk.), seems to be more or less extensively cultivated in Java. In this species Hasskarl mentions six varieties differing in seed characters, but calls attention to no pod differences. The evidence at hand does not yet justify us in deciding whether all of these are really garden varieties or distinct species, but the latter conclusion best coincides with the facts thus far ascertained. Still another species, *Stizolobium hassjoo*, is said to be extensively cultivated in Yezo, the north island of Japan. This last is by far the earliest form yet obtained and will doubtless mature its seed as far north as Tennessee and North Carolina. From a single season's experience it seems to possess unusual merit and will probably come into extensive cultivation, especially for growing with corn.

Detailed notes setting forth the present knowledge of the different forms is given in connection with each species.

GENERAL CHARACTER OF THE GENUS STIZOLOBIUM.

All of the stizolobiums thus far grown are large, annual, much-branched, twining herbs, the stems twining in an opposite direction from the hands of a watch; leaves trifoliate, with large membranaceous leaflets shorter than the petiole; leaflets ovate, the lateral ones oblique, all mucronate, and attached by short, fleshy, very pubescent petiolules; stipules small and lanceolate; stipels bristle-like; flowers in pendent, usually long racemes, the flowers mostly in groups of three; mature pods black, pubescent, marked with one or more longitudinal ridges, or these rarely obscure or wanting.

From an economic standpoint, the species of Stizolobium may be divided into two groups, those which have abundant long stinging hairs on the pods and those which have few or no stinging hairs. The former also have stinging hairs on the calyx. In the former category are to be placed *Stizolobium pruriens* (L.) Medic. (*Dolichos pruriens* L.), the cowhage or cowitch, the type of the genus which is

native to the East Indies but which also occurs now in Jamaica and other West Indian Islands, probably as an introduction; *Stizolobium pruritum* (*Mucuna prurita* Hook. in Wight and Arnott, Prodromus Floræ Indiæ Peninsulæ Orientalis, 1834, vol. 1, p. 255); and *Stizolobium hirsutum* (W. and A.) Kuntze (*Mucuna hirsuta* Wight and Arnott, op. cit., p. 254), both of the latter native to India. Only one of these species with stinging hairs on the pods has matured in our trials, namely, S. P. I. No. 25263, *Stizolobium pruriens* (?). None of these species with stinging hairs can be utilized as forage crops, but they have been grown with the idea of ascertaining their relationship to the more valuable forms.

All of the stizolobiums possess something in the juice, especially in the green pods, which rapidly turns black on exposure to air. This substance blackens the hands and clothing of workmen cutting velvet beans for hay, which is occasionally done. It also causes the dried flowers and pods to become black, and does the same to the seeds of white-seeded varieties, especially if gathered too green or where they press upon each other.

Botanical descriptions and economic notes concerning nine species are presented in this publication.

ANALYTICAL KEY TO THE SPECIES.

Pods velvety with black pubescence.
- Seeds marbled, rarely white, thick, subglobose; pods 2.5 to 3 inches long, nearly as thick as broad ..... *deeringianum.*
- Seeds black, oblong, somewhat flattened; pods flattened, 4 to 4½ inches long, ... *capitatum.*

Pods pubescent, but the pubescence not black or velvety.
- Pubescence dense, erect or nearly so, not appressed.
  - Seeds dull black with faint rusty markings; pubescence of pods tawny. *utile.*
  - Seeds ash colored; pubescence of pods whitish ..... *cinereum.*
- Pubescence white, appressed.
  - Flowers white; leaf surface undulate; seeds ash colored ..... *niveum.*
  - Flowers purple; leaf surface plane.
    - Pod valves with the principal ridge prominent, but secondary ridges rarely more than one.
      - Pubescence on pods rather coarse and long; leaflets 3 to 5 inches long, rather thick; seeds ash colored ..... *hassjoo.*
      - Pubescence very fine; leaflets larger and thinner; seeds shining black ..... *aterrimum.*
    - Pod valves with a well-developed principal ridge and two or more secondary ridges; pubescence soft.
      - Seeds flattened, white with black or gray spots; pods large, very fleshy when green, 5 to 7 inches long; valves with 3 to 5 secondary ridges; pubescence very sparse ..... *pachylobium.*

STIZOLOBIUM DEERINGIANUM.

Stizolobium deeringianum Bort.[a] Florida velvet bean. (Pl. II, *B*.)

An annual, herbaceous, climbing vine, sometimes 20 meters in length when growing on supports, and even on the ground attaining a length of from 2 to 6 meters, bearing long, pendent racemes of purple flowers which produce dark, velvety pods 5 or 6 centimeters long. Stems rather slender, terete, sparsely pubescent with white, appressed hairs, especially on the ridges. Petioles equaling or exceeding the leaflets, pubescent like the stem, and continued for 2 to 4 centimeters beyond the lateral leaflets; stipules subulate, pubescent, about 1 centimeter long; stipels similar but smaller; petiolules about 5 millimeters long, stout, very pubescent. Leaflets rhomboid-ovate, the lateral ones oblique, membranaceous, acuminate-cuspidate, 5 to 15 centimeters long, about half as broad, sparsely pubescent above, especially on the veins, more densely pubescent beneath, the white hairs closely appressed. Inflorescence a raceme or thyrsus 15 to 30 centimeters long, pendent, bearing 5 to 30 flowers, usually about 12; rachis like the stem, but more pubescent; flowers borne singly or in twos or threes on short lateral branchlets. Bracts lanceolate-subulate, very pubescent, early fugacious. Calyx pubescent within and without with short, white, appressed hairs, 2 lipped, the upper lip broadly triangular, the lower lip 3 cleft, the lobes triangular-subulate, the middle one longest; stinging hairs absent. Corolla dark purple, 3 to 4 centimeters long; standard less than half the length of the keel, darker than the rest of the flower; wings slightly shorter than the keel, rather broad, oblanceolate-oblong, obtuse; keel straight to near the tip, where it curves sharply upward, the tip firm and acute; anthers of two sorts, alternately long and short, the latter on much broader filaments; ovary linear, pubescent; style filiform, pubescent nearly to the tip; stigma small. Pods when mature 5 to 6 centimeters long, turgid, densely covered with a soft, nearly black, velvety pubescence without stinging hairs; valves with 1 or 2 or sometimes 3 obscure longitudinal ridges. Seeds 3 to 5 in each pod, subglobose, marbled and speckled with brown or black, and sometimes both, on ash-gray ground color (though pure gray and, it is said, pure black occur rarely), 1 to 1.5 centimeters in diameter. Hilum white, oblong-crateriform, less than one-half the length of the seed.

The leaflets of this species are abruptly mucronate from a usually obtuse apex.

This is the well-known species which has been so long cultivated in Florida. Its importance in late years has grown rapidly, and it is now much more cultivated than ever before. The principal objection to it is the long season required for maturing, which has in a large measure militated against its cultivation farther north. It will, however, make a very large growth of vines as far north as Virginia and Kentucky, but rarely matures its seed north of Florida. It is not well adapted as a hay plant on account of its extreme vininess, and where it does not produce pods is of only limited usefulness. Like all of the stizolobiums it is absolutely immune to the wilt which affects so many other legumes and also to root-knot caused by nematodes. In all of the time this plant has been under cultivation in Florida the only variant produced is one having white or nearly

[a] Bulletin 141, pt. 3, Bureau of Plant Industry, 1909, p. 31.

white seeds, apparently being identical in all other respects with the ordinary form having mottled seeds.

The original source of this species has never yet been determined, though in all probability it comes from southern Asia or some island of the Malay Archipelago. It has been widely distributed throughout the world by the United States Department of Agriculture. Seed which is undoubtedly the progeny of such distributions has been obtained from Saigon, Cochin China (S. P. I. No. 25261), and also from Poona, India (S. P. I. No. 25715). On account of the wide distribution which has been made of the seed of this species, it will be rather difficult to ascertain its exact place of nativity, which can probably be determined only by finding the plant growing under conditions where it is undoubtedly wild.

STIZOLOBIUM CAPITATUM.

Stizolobium capitatum (Roxburgh) Kuntze. (Pl. II, *A*.)

Carpopogon capitatum Roxburgh, Flora Indica, 1832, vol. 3, p. 284.

Mucuna capitata Wight and Arnott, Prodromus Floræ Peninsulæ Indiæ Orientalis, 1834, p. 255.

Roxburgh's original description is as follows:

Annual, twining. Heads axillary, subsessile. Legumes armed with soft velvet-like down.

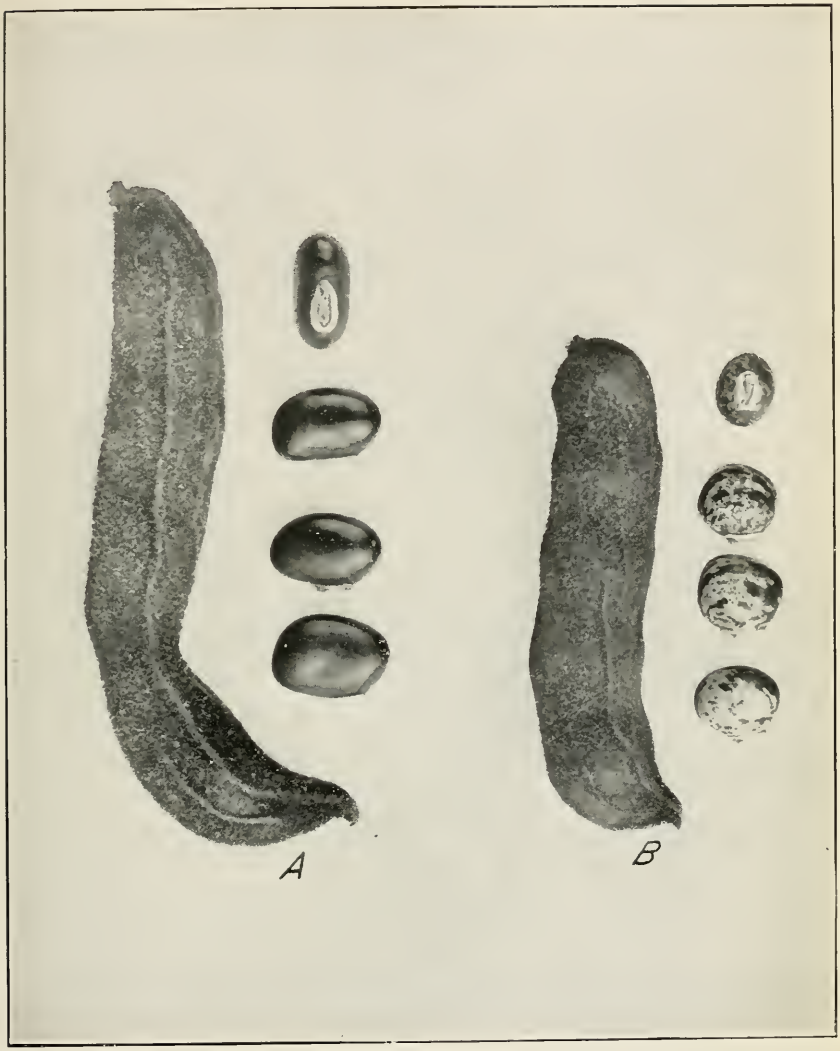
Teling. Soorootoo.

This I have only found in a cultivated state, and that during the cold season, in the gardens of the natives. It is an annual.

Stem herbaceous, twining, branchy, running to an extent of 10 to 12 feet, if supported; young shoots slightly downy. Leaves ternate. Leaflets equal in size, the exterior ones ovate, about 3 inches long and 2 broad, the lateral ones obliquely cordate; all are entire and obtuse, above smooth, a little downy underneath. Stipules of the petioles axillary, short, many flowered. Bracts, flowers, stamens, and pistil as in *C. pruriens*. Legumes cylindric, depending, a little curved, about as thick as the forefinger or thumb, and about 6 inches long, covered with soft, velvet-like down; when ripe wrinkled longitudinally. Seeds five or six, of the size of a small garden bean, smooth, shining, black.

The young pods like those of *Dolichos lignosus* and *lablab* are used by the natives in their curries, after rubbing off the down that covers them.

Pods 9 to 10 cm. long, about 1½ cm. wide, strongly falcate, much compressed, mostly four seeded; valves with a strong central ridge extending from near the base to the tip, a secondary ridge usually present extending for the upper third; pubescence identical with that of *Stizolobium deeringianum*, dense, soft, nearly black, the larger hairs tipped with white; seeds oblong, glossy, black, with or without faint brownish markings, 8 by 15 mm., the white hilum 5 mm. long.



MATURE PODS AND SEEDS OF STIZOLOBIUM CAPITATUM AND STIZOLOBIUM DEERINGIANUM.

A, Pod and seeds of Stizolobium capitatum (seeds, black), S. P. I. No. 22464-A.
B, Pod and seeds of Stizolobium deeringianum, S. P. I. No. 22339.

(Natural size.)

Seed (S. P. I. No. 25120–A) representing this species was obtained from Maj. A. T. Gage, superintendent of the Royal Botanical Garden, Calcutta, British India. This seed was mixed with S. P. I. No. 25120, *Stizolobium utile*, from the same place. At Gainesville, Fla., this same species was mixed with S. P. I. No. 22464, *Stizolobium utile*, obtained through Mr. A. C. Hartless, superintendent of the Government Botanic Garden, Seharanpur, British India, under the name of *Mucuna capitata*. As the seeds of these two species are much alike, the mixture was in each case probably accidental.

This species is the only one having pod pubescence of the type found on the Florida velvet bean, but the pods and seeds are very different. At Biloxi, Miss., and Gainesville, Fla., it matures its pods in about the same length of time as the Florida velvet bean, and probably is of about the same agronomic value.

Later botanical writers have made various comments on Roxburgh's species. Wight and Arnott (Prodromus Floræ Peninsulæ Indiæ Orientalis, 1834, p. 255) quote the herbarium name of Roxburgh, *Dolichos soorootoo*, from an unpublished drawing in the herbarium at Calcutta and also identify the plant questionably with Rumphius's *Cacara nigra*, Plate 138, published in the Herbarium Amboinense. The flowers as indicated on Rumphius's plate are very different from those of any Stizolobium, while the pods resemble closely those of *Pachyrhizus angulatus*. The drawing of the seed, however, indicates a typical Stizolobium. We are unable satisfactorily to identify this plate. Wight and Arnott also state that they have examined specimens collected by Klein, obtained from the Missionaries' Garden. Baker, in Hooker (Flora of British India, vol. 2, p. 187), also refers *Mucuna velutina* Hassk. to this species, a reference which we consider erroneous. A similar reference is also made by Miquel (Flora van Nederlandsch Indië, vol. 1, p. 212). Miquel also refers with doubt to this species the plant described by Rumphius in Herbarium Amboinense as *Cacara nigra*. In this he apparently follows Wight and Arnott.

There could seem to be little doubt regarding the identity of this species as based on Roxburgh's ample description and from the further fact that this plant has been received from Calcutta, the type locality. It does not seem likely that Roxburgh's original plant is *Stizolobium utile*, as the pubescence on the pods of that could scarcely be called velvety. The species is perfectly distinct in its pod characters, in which respect it can only be associated with the Florida velvet bean, which has pods of very different shape and seeds of different shape and color.

STIZOLOBIUM UTILE.

Stizolobium utile (Wall.) n. comb. (Pl. III, *B*).

Mucuna utilis Wall. (Wight, Icones Plantorum Indiæ Orientalis, 1840, vol. 2, p. 280).

Wight publishes an excellent plate of this plant, which has been reproduced in Bulletin No. 141 of the Bureau of Plant Industry, page 28. The only description given by Wight is as follows:

Mucuna utilis (Wall. MSS.). The principal difference of this species, if indeed a species, and *M. prurita* consists in the hairs of its legumes being appressed and almost silky, not erect, rigid, and stinging. In all other respects they sufficiently agree. The flowers in both are purple. The greater size of this is probably attributable to cultivation, in which state only it is known.

Voigt (Hortus Suburbanus Calcuttensis, 1845, p. 235) identifies the plant with "the variety extensively cultivated in the Mauritius and Van Diemen's Land as a table vegetable and also as a fodder for cattle." This plant is the variety with black, shiny seeds commonly known as Mauritius bean. Voigt also gives the name "Pois noir de Bourbon." Cordemoy (Flore de l'Ile de la Reunion, 1895, p. 393) accepts this identification. This author states that the plant on the island of Reunion is known under the name of "Pois mascate." He also gives a detailed description of the plant, which he states was imported into Reunion to serve for breeding purposes, but is now naturalized. We should be inclined to accept this identification if it were not for two facts. First, Wallich's figure indicates more pubescence on the pod than occurs in the Mauritius bean and the pubescence is not closely appressed; secondly, we have obtained from Maj. A. T. Gage, superintendent of the Botanic Garden at Calcutta, seeds of two species of Stizolobium now being grown in the garden at Calcutta. One of these is *Stizolobium capitatum*, already described; the other is the species which we feel confident is the same plant that Wallich has figured. It is very different from the Mauritius bean in that the pod is densely covered with tawny pubescence which is not appressed. The following is a detailed description:

Stems stout, growing 30 to 50 feet long, striate and furrowed, pubescent with fine retrorse hairs; leaflets plane, ovate, 5 to 8 inches long, mostly obtuse, mucronate, puberulent on both sides with fine appressed hairs; racemes 9 to 15 inches long; calyx saccate, pubescent without and within, with fine white appressed hairs, the upper lobe triangular, blunt or notched, the lower lobe one-half longer than the lateral lobes; corolla dark purple, 1½ inches long, the wings broad; ovary densely pubescent with white and purple hairs; pods flattened, 3½ to 4½ inches long, densely pubescent with short erect or ascending tawny hairs with a few purple ones interspersed; lateral ridge strong, more or less broken, extending nearly the length of the valves; seeds oblong, rather thick, 12 to 14 mm. long, dull black, faintly marked with brown flecks, the veins invisible.

MATURE PODS AND SEEDS OF STIZOLOBIUM CINEREUM AND STIZOLOBIUM UTILE.

A, Pod and seeds of Stizolobium cinereum, S. P. I. No. 22463.

B, Pod and seeds of Stizolobium utile (seeds, dull black), S. P. I. No. 22464.

(Natural size.)

This is S. P. I. No. 25120, obtained from Maj. A. T. Gage, superintendent of the Botanic Garden at Calcutta, British India. Identical with it is S. P. I. No. 22464, from Mr. A. C. Hartless, superintendent of the Government Botanic Garden, Seharanpur, British India.

This species has been grown for two seasons at Biloxi, Miss., and Gainesville, Fla. It matures with the Florida velvet bean and is about as productive. The pubescence on the pods, however, is rather harsh, rubs off easily, and is irritating to the skin. On this account it will doubtless not be found desirable for cultivation.

STIZOLOBIUM CINEREUM.

Stizolobium cinereum n. sp. Ashy-pod bean. (Pl. III, *A*.)

Stems stout, growing 30 to 50 feet long, furrowed, covered with a fine, harsh pubescence, the hairs not retrorse; leaflets plane, broadly ovate, mostly obtuse, mucronate, 5 to 8 inches long, pubescent on both sides with appressed white hairs, especially beneath; racemes 9 to 15 inches long; calyx saccate, silky with white appressed hairs without, less so within; corolla dark purple, 1¼ inches long; pods flattened, 4 to 4½ inches long, densely pubescent with short erect or ascending white hairs; median ridge prominent, complete, the secondary irregular, varying from continuous to broken or sometimes wanting; seeds oblong, ash colored, the ends often black, veiny, about 15 mm. long.

This species has been grown for two seasons at Biloxi, Miss., and Gainesville, Fla. It matures with the Florida velvet bean, but is no more prolific and the hairs are irritating.

This is S. P. I. No. 22463, from Mr. A. C. Hartless, superintendent of the Government Botanic Garden, Seharanpur, British India.

STIZOLOBIUM NIVEUM.

Stizolobium niveum (Roxburgh) Kuntze. Lyon bean. (Pl. IV, *A*.)

Carpopogon niveum Roxburgh (Flora Indica, 1832, vol. 3, p. 285).

Mucuna nivea Wight and Arnott (Prodromus Floræ Indiæ Peninsulæ Orientalis, 1834, p. 255).

Mucuna lyoni Merrill (Philippine Journal of Science, Supplement 1, 1906, p. 197).

Roxburgh's original description is as follows:

Annual, twining. Racemes pendulous. Legumes from six to eight seeded, while young downy; when old destitute of down and wrinkled.

Bengal-Khamach.

Like *Carpopogon capitatum*, I have only found this in a cultivated state, and even then very uncommon, having seen it but in one or two gardens near Calcutta; however, if it is not indigenous in Bengal, it must have been long known to the natives, not only on account of their having a vernacular name for it, but because it is eaten by them, as a Hindoo requires a long and intimate acquaintance with any article before he makes it a part of his diet. Potatoes they must have known fifty years or more before they began to admit them at their tables.

Be that as it may, the plant is cultivated during the cold season, when it blossoms and produces fruit in great abundance.

Root ramous, generally annual, though in some soils it lasts longer. Stem twining to an extent of some fathoms, very ramous and thick, but of a spongy, succulent nature, young shoots a little villous. Leaves ternate. Leaflets entire, the pair nearly semicordate, the terminal one rhomboidal; all have short acute points and are nearly equal in size, of a soft delicate texture and slightly villous on both sides; from 4 to 10 inches long. Petioles round, slightly villous, from 6 to 12 inches long. Stipules lanceolate. Racemes axillary, solitary, pendulous, often as long or even longer than the leaves, bearing numerous, three-fold, pendulous, very large white flowers. Bracts fourfold, a common one to each tubercle of the racemes, on which the three flowers are inserted, and one to each of the proper pedicels, all are caducous, nearly lanceolate, and villous. Calyx four parted. The upper division broad and emarginate; the lower one narrowest and more lengthened than the lateral pair. Corol papilionaceous. Banner cordate, incumbent on the wings and keel, and about half their length. Wings oblong, with a remarkable callous gland near the base of each. Keel one petalled, linear, length of the wings, with a sharp, rigid, incurved point. Nectary a crenulate gland round the insertion of the germ. Filaments one and nine, alternately clavate and filiform, with long linear, subsagittate anthers on the slender filaments, and short-ovate ones on the clavate ones. Germ hairy. Style slender and villous. Stigma small. Legume linear, about 6 inches long, curved a little like an italic *S* when ripe, black, destitute of down, and longitudinally wrinkled. Seeds generally from six to eight, oval, smooth, ash colored, and separated by thin partitions.

By removing the exterior velvet-like skin of the large, fleshy, tender legumes, they are when dressed, like French beans (*Phaseolus vulgaris*), a most excellent vegetable for our tables, and the full-grown beans are scarcely inferior to the large garden beans of Europe.

We identify as this species S. P. I. No. 24936, obtained through Mr. C. Drieberg, of the Ceylon Agricultural Society, Colombo, Ceylon, which at Biloxi, Miss., and Gainesville, Fla., proved indistinguishable from *Mucuna lyonii* (S. P. I. No. 19979) obtained from the Philippines. The original specimens of *Mucuna lyonii* came from Pampanga Province, Luzon, there called "Sabual." This is the only species obtained by us with ash-colored seeds that has white flowers. Wight and Arnott,[a] in discussing *Mucuna capitata*, comment as follows:

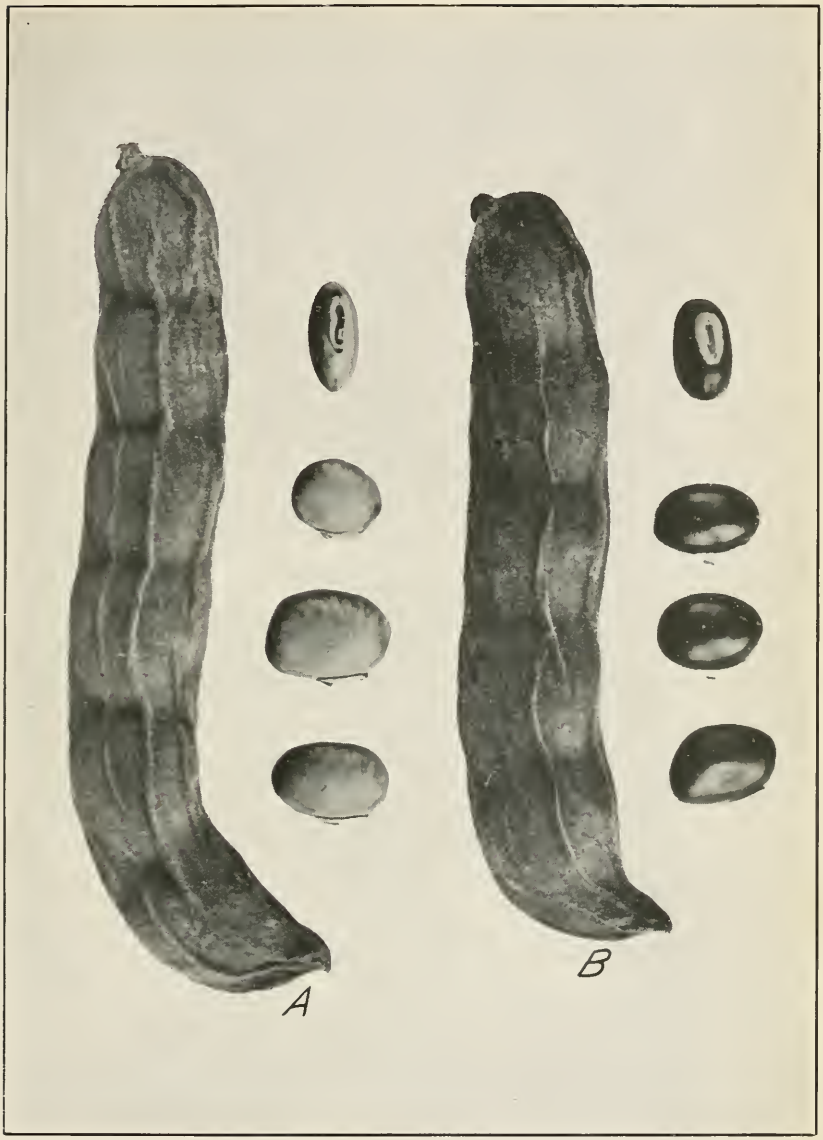
M. niveum, D. C. (*Carpopogon niveum*, Roxb. in East India Company, mus. tab. 1601) is a species very closely allied, but differs by the long drooping racemes and the legumes when ripe, entirely free from pubescence; it likewise is only known as a cultivated plant.

Watt's Dictionary of the Economic Products of India, 1891, vol. 5, p. 285, comments as follows:

Met with in Burma and Bengal, perhaps only a cultivated variety of *Mucuna pruriens*.

Cultivated during the cold season for the sake of its abundant and useful fruit. The large, fleshy, tender legumes have long been known and valued as a vegetable by the Hindus, and, according to Roxburgh, are, when dressed, like French beans, a most excellent vegetable for European tables.

[a] Op. cit., p. 255.



MATURE PODS AND SEEDS OF STIZOLOBIUM NIVEUM AND STIZOLOBIUM ATERRIMUM.

A, Pod and seeds of Stizolobium niveum, S. P. I. No. 19979.

B, Pod and seeds of Stizolobium aterrimum (seeds, shining black), S. P. I. No. 21300.

(Natural size.)

Watt also states that the vernacular names in use in Bengal are "Khamach" and "Alkushi." Firminger (Manual of Gardening for India, p. 133) says: "To me the beans seem to partake rather of the agreeable flavor of the Lima bean, and afford a very nice dish during the latter end of the rain season." Baker in Hooker (Flora of British India, vol. 2, p. 188) quotes *Mucuna nigra* Ham. (in Wall. Cat. 5617) as a synonym, but neither description nor citation accompanies the publication of that name.

The Lyon bean has now been cultivated in Florida and other Southern States for three years. It requires about the same length of time to mature as the Florida velvet bean, or is perhaps slightly earlier. It is, however, much more prolific in seed production and is therefore likely to come into prominent use. Besides its greater productivity it has the advantage over the Florida velvet bean of being wholly devoid of stinging hairs. The leaf surface, unlike any other species known to us, is decidedly undulate, so that the plant can readily be recognized even before it blooms. The vine is fully as ornamental as the Florida velvet bean and should become a popular arbor plant, especially if the seeds are as edible as indicated by Roxburgh and others.

Prof. P. H. Rolfs, of the Florida Agricultural Experiment Station, and five other persons tested the edibility of the seeds prepared as baked beans. While they were found to be very palatable, they caused both purging and vomiting. Three of the persons who ate about half as much of the dish as they would of ordinary baked beans were thus affected. The other three who ate of them very sparingly suffered no ill effects.

The pods and seeds of this species are well represented in Plate IV, *A*. The flower clusters are longer than in any other species.

STIZOLOBIUM HASSJOO.

Stizolobium hassjoo n. sp. Yokohama bean. (Pl. V, *B*.)

Vines slender, 6 to 20 feet long, sparsely pubescent with retrorse white hairs; leaflets ovate, acutish, abruptly mucronate, rather thick and firm in texture, plane, 4 to 5 inches long, sparsely pubescent on each face with white appressed hairs; racemes 4 to 6 inches long; flowers dark purple; calyx saccate, the lower lobe one-half longer than the lateral ones, densely appressed-pubescent without and within; corolla 1½ inches long; pods 4 to 4½ inches long, 5 to 6 seeded, covered with rather long white appressed pubescence; median ridge prominent, the secondaries faint or wanting; seeds ash colored, often blackish at the ends, oblong, flattened, 15 to 18 mm. long, the veins of the testa very obscure.

This is S. P. I. No. 25254, obtained from the Yokohama Nursery Company, Yokohama, Japan, who state that this plant is widely grown in Hokkaido or Yezo, the north island of Japan. In the "Useful Plants of Japan," 1895, page 9, where it is erroneously iden-

tified with *Mucuna capitata* Wight and Arnott, the following information is given:

Jap. *Osharaku-mame, Hassho-mame;* an annual leguminous climber cultivated in common dry land. The young soft grains are eaten boiled and have a taste of *Vicia faba* L., but this bean contains a poisonous ingredient in a slight quantity; so it is advisable to eat moderately.

Stizolobium hassjoo is by far the earliest species known to us. Planted at Biloxi, Miss., April 19, 1909, it was perfectly mature and dry on September 20; at Gainesville, Fla., it was fully mature by September 27, having been planted on May 1; at Monetta, S. C., it was planted June 15 and the pods were mature enough to ripen when the vines were killed by frost on October 25; at the Arlington Experimental Farm, near Washington, D. C., it was in full bloom on October 12, having been planted on June 21. The individual plant will cover a plat 3 to 4 feet square, which will indicate the proper distance to plant.

This species was also grown at Manhattan, Kans., in 1890 under the name *Mucuna capitata*, by Prof. C. C. Georgeson. From seed planted May 19 the plant began to bloom August 7 and matured a few pods before frost.[a]

This plant is mentioned by Siebold (Verhandelingen van het Bataviaasch Genootschap, 1830, vol. 12, p. 55) under the name *Dolichos hassjoo*, and the Japanese name "Hassjoomame" is cited, but no description given. We have thought it best, however, to use the same specific name.

STIZOLOBIUM ATERRIMUM.

Stizolobium aterrimum n. sp. Mauritius or Bengal bean. (Pl. IV, *B*, and Pl. VII.)

Vine very strong and vigorous, the stem striate but scarcely furrowed, covered with a soft, sparse pubescence; leaflets very large, plane, mostly acute, strongly mucronate, sparsely appressed-pubescent on each side; racemes pendent, 18 to 30 inches long, many flowered; flowers purple; calyx not saccate, densely appressed-pubescent without and within; pods falcate, about 4 inches long, black when mature, sparsely covered with a short, white, appressed pubescence; median ridge on valves prominent but sometimes broken; secondary ridge faint or wanting; seeds four or five, oblong, black, very shiny, 10 to 12 mm. long, the prominent hilum white.

This species is apparently much more widely cultivated than any other and has been obtained from the following sources:

S. P. I. Nos. 19181 and 21300, from Piracicaba, Brazil.
S. P. I. No. 22031, from Sydney, New South Wales, under the name "Black Mauritius bean."
S. P. I. No. 22032, from Kamerunga, Queensland, Australia, under the name "Black Mauritius bean."

[a] See Kansas Agricultural Experiment Station, Bulletin 19, December, 1890, p. 199.

MATURE PODS AND SEEDS OF STIZOLOBIUM PACHYLOBIUM AND STIZOLOBIUM HASSJOO.

A, Pod and seeds of Stizolobium pachylobium, S. P. I. No. 21094.
B, Pod and seeds of Stizolobium hassjoo, S. P. I. No. 25254.
(Natural size.)

S. P. I. No. 25262, from Saigon, Cochin China.
S. P. I. No. 24922, from Saigon, Cochin China.
S. P. I. No. 25870, from Barbados, under the name "Bengal bean."
S. P. I. No. 25755, from Mauritius.
S. P. I. No. 21951, from Buitenzorg, Java.
S. P. I. No. 21953, from Buitenzorg, Java.
S. P. I. No. 24935, from Colombo, Ceylon.

This species is also grown in Hawaii under the name of Mauritius bean, and has been obtained from Brazil under the name of Horse-Eye bean.

Both at Biloxi, Miss., and at Gainesville, Fla., this species grows to a much larger size than the Florida velvet bean, but is much later, so that the pods barely mature. On account of its extreme lateness it is not at all likely that it will be of value under American conditions. In Barbados Mr. John R. Bovell, the Superintendent of Agriculture, writes that it is grown to only a small extent for green manuring. He has never known it to be used for fodder or as human food.

In Mauritius, according to Director P. Boname, of the agricultural station at Reduit, the Florida velvet bean has proved to be much less luxuriant and valuable.

As already stated, this plant was identified by Voigt as the *Mucuna utilis* of Wallich. For the reasons given in the discussion under *Stizolobium utile*, we regard this identification as erroneous. There is still slight room for doubt in connection with this matter, which, however, can only be cleared up by comparison with the original type.

STIZOLOBIUM PACHYLOBIUM.

Stizolobium pachylobium n. sp. Fleshy-pod bean. (Pl. V, *A*, and Pl. VI.)

Vines stout, 40 to 60 feet long; stems sparsely pubescent with soft white hairs; leaflets 3 to 7 inches long, mostly acute, cuspidate, sparsely appressed-puberulent on both sides, especially on the veins beneath; racemes 1 to 2 feet long, the peduncle often bearing a small leaf; flowers dark purple, 1½ inches long; calyx appressed-puberulent without and within, the lower lobe little exceeding the laterals; pods large, 5 to 7 inches long, very fleshy when green, sparsely puberulent with weak white hairs, black and slightly falcate when mature, somewhat compressed, the valves mostly having two complete longitudinal ridges and several secondary ones; seeds much flattened, 18 to 22 mm. long, white with scattered black or gray spots.

The original seed of this, S. P. I. No. 21094, was presented to the Department by Mr. J. C. Vaughan, of Chicago.

It was sent to him by Mr. A. L. Kennan, from Talgarh, Midnapur, India, who writes: "The spotted bean is very productive, but is cultivated to a very limited extent by the Santals, one of the aboriginal tribes of India. They cook the green pods and also the ripened seeds, but do not like either very well."

This has larger seeds than any other species, and the pods also are the largest and least pubescent. It requires, unfortunately, a longer season than the Florida velvet bean by at least a month. Some of the clusters of pods of this bean measure 3 feet in length and bear over 50 pods.

The edibility of the pods and seeds has been tested by Mr. S. H. Gaitskill, of McIntosh, Fla., who writes:

> We have been giving the fleshy-pod velvet bean a trial. I could not get the negroes to try it until I had eaten it and had Mr. Dedman try it; then the negroes tried it. I do not consider it a fine-flavored bean, but has no bad taste; in fact, is quite palatable, and there were no bad effects at all. I would call it an edible bean.
>
> We found the bean better than the pod, and it might be that it would be more palatable to let them get fairly ripe and use them as shelled beans.

An important characteristic in which this species differs from the others is that the pods do not dehisce at maturity, but the pods can be broken in pieces without the valves separating. This character will very likely be valuable in crossing with the Lyon bean and others which dehisce rather too easily and thus shatter seed.

STIZOLOBIUM VELUTINUM.

Stizolobium velutinum (Hassk.) n. comb.

Mucuna velutina Hassk. (Beiblätter, p. 77, to Flora, 25th year, 1842, vol. 2.)

The original description is as follows:

Mucuna velutina. Nom. sund. *Kwas boddas.*

Legumina lamellis transversis fere distituta:—Racemis abreviatis 6—4, 5 poll. long. 0, 5 pll. crassis densissime velutinis subtereti-oblongis apice curvatis 6-loculatis, seminibus compressis;—foliolis (lateralibus oblique–) ovatis mucronulatis utrinque pilis adpressis minutissimus sparsis (in junioribus & calyce sericeis); corolla alba. Caulis volubilis, petioli pedales, stipellæ subulatæ,—Spec. intermedia M. mitem inter & mollem DC. Prdr. II. 405.

Hasskarl later published a modified description (Catalogus Plantarum in Horto Botanico Bogoriensi, 1844, p. 277), as follows:

Mucuna velutina. Kwas.

Floribus racemosis, bracteis subnullis, leguminibus densissime velutinis subtereti-oblongis, apice curvatis vix 6– (sub 1–) loculatis, foliolis ovatis mucronulatis utrinque pilis minutissimis adpressis sparsis.—Variat seminbus nunc maculatis majoribus minoribusve (Kw. boeriek gedeh & leutiek) nunc immaculatis albis rugosis s. lævibus (Kw. boddas mengrœt & lietjieu) aut viridiusculis aut nigris (Kw. heedjoh s. hiedung).

Through the kindness of Dr. M. Treub, director of the Buitenzorg Botanical Garden, we have obtained seeds of all the sorts now grown there. These include the following S. P. I. Nos.: 21951 and 21953, with black shiny seeds; 21952, with ash-colored seeds; 24657, marbled ash and brown; 24424, reddish to pinkish gray, more or less marbled with black or brown; 21955, greenish yellow or brownish, clouded

CLUSTER OF RIPE PODS OF FLESHY-POD BEAN (STIZOLOBIUM PACHYLOBIUM) GROWN AT McINTOSH, FLA.

(Two-sevenths natural size.)

CLUSTERS OF GREEN PODS OF MAURITIUS BEAN (STIZOLOBIUM ATERRIMUM), S. P. I. No. 24922, GROWN AT GAINESVILLE, FLA.

(One-third natural size.)

over with black, perhaps the same as 24424, but with discolored seeds. There was also found in some asparagus bean seed from Buitenzorg a variety with greenish-yellow seeds, No. 0840.

Doctor Treub writes, under date of April 26, 1909:

> The three varieties described by Hasskarl, (1) "Kwas boeriek," (2) "Kwas hiedung," (3) "Kwas boddas," are now grown in our botanical garden under the following names: (1) *Mucuna velutina* Hassk. var., (2) *Mucuna capitata* var. *nigra*, (3) *Mucuna capitata* var. *alba*. The subvariety described by Hasskarl with rough seeds ("Kwas boddas mengroet") seems to be no more present.

It will be noticed, however, that there were received from Buitenzorg more kinds than Doctor Treub mentions. Of these S. P. I. Nos. 21955 and 0840 failed to germinate; Nos. 21951 and 21953, with black, shiny seeds, proved to be identical with the Mauritius bean; No. 21952, with ash-colored seeds, is a very late sort with purple flowers, but the pods did not mature; Nos. 24424 and 24657, both with marbled seeds, also did not mature at Biloxi, Miss., or Gainesville, Fla., but have been grown to maturity in the greenhouse.

Since Hasskarl in his first description referred only to "Kwas boddas," that is clearly the type of the species. It will be noted that in the first description Hasskarl states that this has white flowers. According to his second description, Kwas boddas has white seeds, rough in one form and smooth in the other, but the color of the flowers is not mentioned.

In a comparatively recent publication from the Buitenzorg Garden, Burck (Annales du Jardin Botanique de Buitenzorg, 1893, vol. 11, p. 187) considers *velutina* identical with *utilis* and reduces both it and *capitata* to varieties of *Mucuna pruriens*. According to him, var. *utilis* (*velutina*) has the seeds white, fuscous, or fuscous-maculate. He does not specify the color of the seed of var. *capitata*.

None of the kinds that we have secured from Buitenzorg and grown fulfills these conditions of white flowers and white seeds, as all that grew had purple flowers and only one had seeds that can be called white. There remains S. P. I. No. 0840, with greenish-yellow seeds. This seems to be identical with S. P. I. No. 25756, received from Mauritius, and that does have white flowers. This, however, would seem to fit best with Hasskarl's "Kwas heedjoh," the seeds of which are described as greenish, "viridiusculis."

We are therefore at a loss to determine the identity of the real *Mucuna velutina*, which seemingly is not contained among those grown by us, unless it may indeed be identical with *Stizolobium niveum*, the only species we as yet know with white flowers and white seeds.

As before stated, the species with black, shiny seeds proves to be the same as the Mauritius bean. The two kinds with mottled seeds are probably distinct species.

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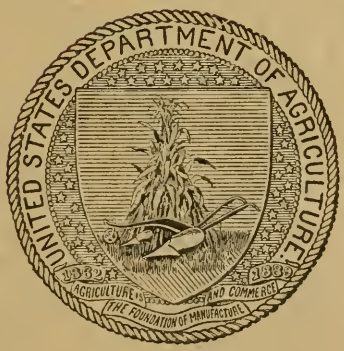
BUREAU OF PLANT INDUSTRY—BULLETIN NO. 180.
B. T. GALLOWAY, *Chief of Bureau.*

AGRICULTURAL AND BOTANICAL EXPLORATIONS IN PALESTINE.

BY

AARON AARONSOHN,
DIRECTOR OF THE JEWISH AGRICULTURAL EXPERIMENT STATION AT HAIFA, PALESTINE.

ISSUED AUGUST 4, 1910.



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B. T. GALLOWAY, *Chief of Bureau.*

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AARON AARONSOHN,
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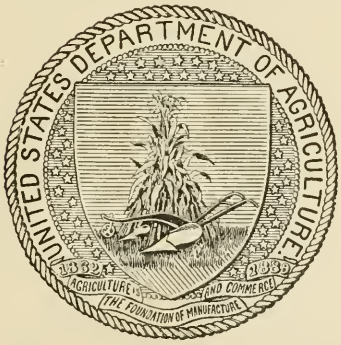

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., February 4, 1910.

Sir: I have the honor to transmit herewith a paper entitled "Agricultural and Botanical Explorations in Palestine," by Mr. Aaron Aaronsohn, Director of the Jewish Agricultural Experiment Station at Haifa, Palestine, and to recommend its publication as Bulletin No. 180 of the series of this Bureau.

The paper contains a summary of agricultural observations on a considerable number of economic plants indigenous in Palestine, more particularly cereals, that are considered worthy of introduction into the United States, the very close similarity of the natural conditions of Palestine to those of California and the adjacent States of the Southwest being pointed out. At the suggestion of Mr. David Fairchild, Agricultural Explorer in Charge of Foreign Seed and Plant Introduction, Mr. Aaronsohn has spent several months in the United States inspecting our agricultural industries and experiments in the interest of his work in Palestine and in studying American conditions, especially in dry-land regions. This experience has peculiarly fitted him to recognize plants adapted for introduction into America.

Mr. Aaronsohn is known in the scientific world for his botanical explorations of Palestine, and particularly for his discovery of the wild emmer, from which our cultivated types of wheat and related cereals seem to have been derived. This plant was found to cover large areas on the slopes of Mount Hermon. The study of wild ancestral forms of our cultivated plants is yielding many facts of practical assistance in the work of introducing, acclimatizing, and breeding improved varieties adapted to the endlessly varied conditions found in the United States.

Respectfully,

G. H. Powell,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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AGRICULTURAL AND BOTANICAL EXPLORATIONS IN PALESTINE.

INTRODUCTION.

The economic and agricultural importance of the Orient is beginning to be appreciated in the United States more than anywhere else. Agricultural explorers have not only brought back important economic and ornamental plants, but have gained broader views and have seen the possibilities for a wonderful new development in agriculture. They have learned in the Orient that there is every reason to hope that the vast arid and semiarid regions of America can be rendered productive, although from the point of view of the European agronomist they would appear as worthless deserts.

Economic exploration rather than scholarly research is needed to make the countries of the Orient known and appreciated abroad and to renew a belief in the ancient saying "ex Oriente lux" (light comes from the Orient). The United States may expect its most valuable agricultural introductions from the Orient. The Smyrna fig and the Thompson Seedless grape have already been brought from the Orient, to mention only two examples of fruits. From the Orient have also come the oats of Kherson and the hard wheats of Russia and Turkey, which have made it possible to extend the cultivation of cereals to regions that were uncultivated before their introduction. But this is only the beginning. My own observations in the Orient, as well as in the Middle West and Southwest regions of the United States, lead me to believe that all that has been done in this direction is only a splendid beginning.

In fact, the Orient still remains almost unexplored and unknown as to its agricultural possibilities. In the oriental countries can be found almost all of the wild types which our prehistoric ancestors utilized in producing the cultivated crops of our time. Here, also, are to be found some of the best cultivated varieties, developed by the combined efforts of man and nature for thousands of years. New countries, especially those of the west, can here obtain the plants best adapted to their needs.

An idea of what the Orient holds for those who will take the trouble to explore it can easily be gained by considering the useful

plants which I think should be introduced from Palestine, a part of the Orient which I have made my special study.

ANALOGY BETWEEN PALESTINE AND CALIFORNIA.

Palestine is more like the State of California than any other in the Union in everything except size. It lies between longitude 34° 30′ and 36° 30′ east, and between latitude 30° 30′ and 33° 45′ north. It is practically a California reduced to about one-twentieth in size, but markedly similar in general topography, climate, vegetation, and agricultural and economic possibilities.

GENERAL CONFORMATION OF PALESTINE.

Like California, Palestine (see fig. 1) is longest from north to south. Like California, too, it has both very high mountains, having an elevation of 9,000 to 10,000 feet, and very deep depressions. The Dead Sea, 1,200 feet below sea level, is the greatest depression known, and, like the Death Valley of California, it is situated in the southern extremity of the country.

Such formations always give rise to a great diversity of soil and vegetation. Where a very ancient civilization exists, as in Palestine, such formations likewise favor the development of many varieties of cultivated plants and give rise to different methods of cultivation.

Passing from west to east, we have in Palestine (see fig. 2) the coast zone, extending along the Mediterranean, similar to the littoral region of the Pacific, and the zone of hills and plateaus of the mountains of Judea and Galilee, forming, so to speak, the backbone of the country and being similar to the foothill region of California. Farther east we have the valley of the Jordan, the diversified parts of which are similar in soil, climate, and agricultural possibilities to the San Joaquin, Imperial, and Death valleys. Finally, still farther east are the plateaus of the Trans-Jordan, with their fertile soils of volcanic origin, devoted from time immemorial to pastures and the cultivation of cereals. They are regarded as the granary of the country and have been famed since Bible times for the abundant herds of Bashan. Extending eastward these plateaus pass into the steppes and, finally, toward the south, form the deserts of Syria and Egypt.

CLIMATE AND RAINFALL OF PALESTINE.

In Palestine, just as in California, we have a dry, warm season and a humid and more temperate one. The rainy season extends from October to May, and the dry season from May to October. The rainfall varies, according to the locality, from less than 6 inches in the extreme south near the Egyptian frontier, where rains are insufficient and uncertain, to more than 40 inches in the north of the country.

Palestine is even more favored than California with regard to the winter temperature. Although the thermometer rises as high in summer in Palestine as in California, with extremes of 110° to 115° F., though not so often, it very rarely drops in the winter to the freezing

FIG. 1.—Relief map of Palestine, showing the coast region, the Jordan Valley, and the unexplored regions of the east.

point. Snow is rare, even on the plateaus, and our farmers are practically safe from any damage by frost over nearly the entire extent of the country.

GEOLOGICAL FORMATIONS OF PALESTINE.

Geologically the Paleozoic age in Palestine is represented in the extreme southeast by granite and gneiss; the Secondary formations

FIG. 2.—Map of Palestine, showing the location of the principal towns and villages.

appear in the extreme northeast in the Jurassic, and the Cretaceous is found everywhere in the form of sandstone, hard limestone, and

dolomite belonging to the Cenomanian and Turonian ages and soft limestones and beds of flint being generally attributed to the Senonian age. Finally, my own discoveries have shown that the lower Eocene of the Tertiary age, which was unrecognized for a long time, covers a vast area here. This formation is abundant in the south, where erosion has reduced it to thin layers, and in the north, where it is characterized by nummulitic limestone. Finally, there are the Pliocene and the Pleistocene, the alluvial, diluvial (see Pl. I, fig. 1), and volcanic deposits, which in the form of basalt and basaltite are found over vast stretches of territory in Samaria and lower and upper Galilee, and especially in the Trans-Jordan. The Trans-Jordan is very similar to the vast volcanic region of California and Oregon, and to that of Idaho in the neighborhood of Pocatello and in other localities in that State.

Because of its diversified geologic formations the country presents a great variety of soils, but fortunately the calcareous element predominates, for it is this element which is of the greatest importance in the soils of arid and semiarid regions, being second in importance to water only, which is indispensable for maintaining animal and vegetable life.

As is to be expected from this great variety of soil and climate, the vegetation of Palestine is remarkably rich in species and presents types of both desert and alpine floras.

VEGETATION OF PALESTINE.

Curiously enough, the list of the flora of the small territory of Palestine includes approximately the same number of species as that of California—about 3,000. This is nearly twice as many as are known in Algeria, which has the same variations of soil and climate as Palestine but is about fifteen times as large.

There are many other points of similarity between the vegetation of California and that of Palestine. In both sections evergreen shrubs predominate. The same forms of vegetation, often the same genera, are found on Mount Tamalpais, California, and on Mount Carmel, Palestine; the maqui formation of Palestine is to be compared to the chaparral and chamiso of California, and the forms of vegetation of the Lebanon and the Hermon mountains are much the same as those of the western slope of the Sierras.

On account of the predominance of the calcareous element in the Palestine soils already mentioned, the lime-loving leguminous plants are well represented. The genera Medicago, Melilotus, Trigonella, Astragalus, Trifolium, etc., are rich in species which aid in maintaining fertility by means of their nitrogen-fixing character. These furnish good temporary pastures in winter and spring, and during

the long, dry summers the cattle relish the hulls which cover the ground. The introduction of these remarkable leguminous plants into the Southwest, and their cultivation and selection, may be expected to contribute greatly to the improvement of the range. This analogy of the flora of Palestine with that of California justifies our expectation of the best results. The plants of Palestine are, so to speak, the homologues of those of California, and, a priori, their success seems assured.

The success of the useful xerophytes (see fig. 3) and halophytes of the Palestine deserts when introduced into the Southwest ought

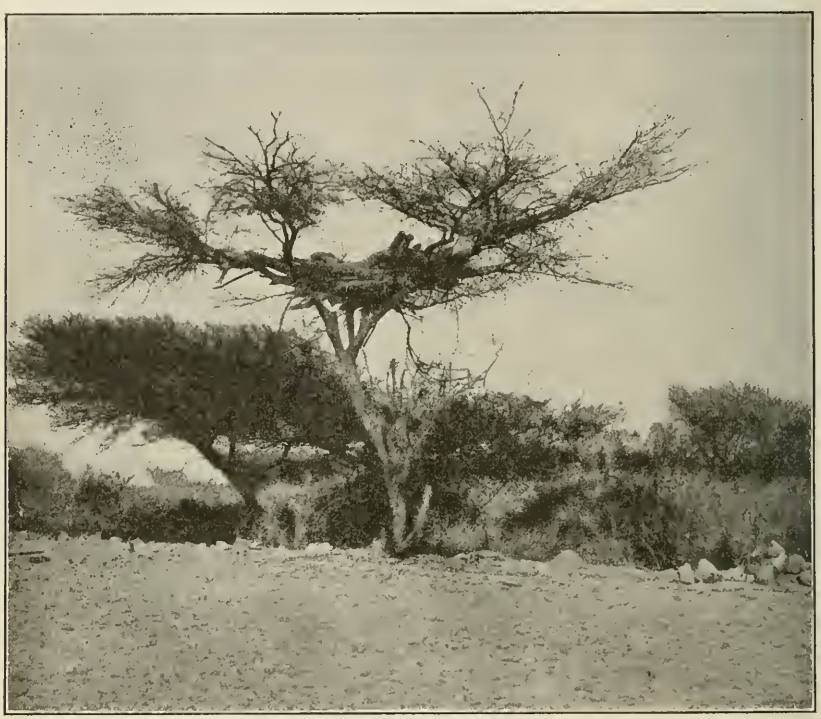

FIG. 3.—Seyal acacia tree near Engedi, on the western shore of the Dead Sea. The rough flooring in the branches is used by Arabs as a summer dwelling.

to be even more certain than would that of the plants of the Southwest if transferred to Palestine, and for the reason that in the desert districts surrounding Palestine the rains come, when they come at all, only during a single short season between October and March. On the contrary, in Arizona, for example, there are two rainy seasons during the year. This would be a great advantage to the leguminous annuals and grasses introduced from Palestine.

In the territory with which we are dealing we have, as has been shown, a large number of wild species and varieties. If we consider the varied natural conditions of Palestine and the peculiar

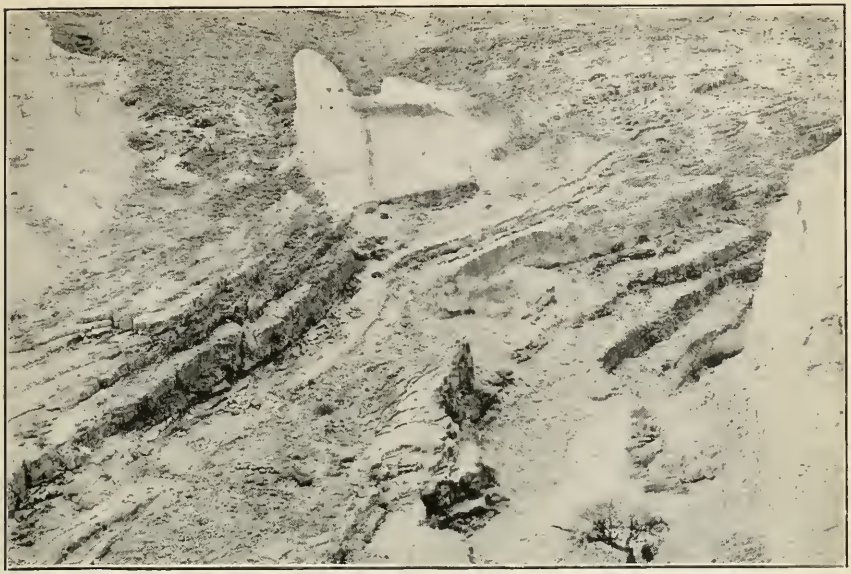

FIG. 1.—KASR-EZZUWEIRA, SHOWING THE EFFECTS OF EROSION ON THE "LISSAN" STRATA, LAYING BARE THE UNDERLYING ROCKS.

FIG. 2.—VIEW OF SAFED. ON THE LEFT IS THE ROCKY MOUNTAIN, DESTITUTE OF FOREST VEGETATION, WHERE TRITICUM DICOCCUM DICOCCOIDES WAS FOUND.

methods of cultivation which have been brought about by political conditions—the vicissitudes of war, the continual migration of tribes, and colonization—all acting through such long periods of time, we can readily understand why so many varieties of cultivated plants have been developed and why the country is such an interesting one to study and is so full of promise.

ECONOMIC PLANTS WORTHY OF INTRODUCTION INTO THE UNITED STATES.

PLANTS RECOMMENDED AS STOCKS.

Zizyphus spina-christi (*Christ-thorn*).—This tree averages 16 feet or more in height, with a diameter of 16 to 24 inches. Its fruit, about the size of a hazelnut, is not so well liked as that of the species mentioned later. It is a tree which is found along the coast and in the valley of the Jordan. There are several local races adapted to different life conditions. In the valley of the Jordan, and especially farther south in the valley of the Arabah, it is the most common tree on alkaline soils.

The Arabs water their land very abundantly and do not provide any drainage, and as a consequence great quantities of alkaline salts are brought to the surface. At the end of two or three years the soil is so excessively salty that the land is abandoned for a number of years until the rains have washed the salt down into the subsoil. *Zizyphus spina-christi* grows on these lands abandoned on account of their excessive alkalinity, so that when an explorer finds a field overgrown with this plant he can be sure that it has formerly been under cultivation.

Zizyphus spina-christi inermis.—In very moist lands along the banks of streams, for example those of the Jordan near Jericho, the type plant loses its thorns (thorny stipules or stipular spines). The resulting variety is called *inermis* (spineless).

Zizyphus lotus.—This bush rarely grows to a height of 6 feet. It tends rather to give off suckers, thus spreading continually and forming clumps of large diameter. This characteristic makes the plant very valuable for the fixation of dunes. It seems to be more particularly adapted to inland dunes, although it has been grown successfully along the coast. The fruit of this species, although smaller than that of *Z. spina-christi*, is more palatable and, under the name of "Dôm," is eaten dry by the Arabs throughout the valley of the Jordan, and also by the Jews of Tiberias. The taste is a little like that of dried apples.

Zizyphus lotus seems to be less adapted to alkaline ground than *Z. spina-christi*, but grows on the most arid hills. In the vicinity of Tiberias and farther south and east it is the only bush which

grows on the black basalts, where in summer a burning temperature prevails.

I believe that *Zizyphus spina-christi* and *Z. lotus* may be of great value as stocks for Chinese jujubes or t'saos (*Z. sativa*) and that by their use we can extend the cultivation of this fruit to regions where it is now absolutely impossible on account of excessive dryness or excessive alkalinity of the soil. These stocks seem to me to be especially adapted to the Imperial Valley of California.

Paliurus spina-christi.—Another species related to the two already mentioned is *Paliurus spina-christi.* This is a bush 10 to 13 feet high. It does not extend so far south as the two preceding species, but thrives on the plateaus of upper Galilee, where it is used for hedges around unirrigated olive plantations, and also at the foot of Mount Hermon, where hedges of it are planted around irrigated fields.

This species, also, should be tried as a stock for the Chinese jujube. It is adapted to less arid soils than *Zizyphus lotus* and does well on those having a considerable degree of moisture and in regions where the winters are relatively severe.

If these three species, *Zizyphus spina-christi*, *Z. lotus*, and *Paliurus spina-christi*, graft readily with the Chinese jujube, we shall have stocks for this fruit available for all kinds of soil—moist, arid, and alkaline—and for both high and low altitudes—from 3,300 to 4,000 feet above to 1,300 feet below sea level.

Pistacia terebinthus and Pistacia palaestina.—These species will furnish stocks for *Pistacia vera*, the true pistache nut, a crop which can be made of great value in the United States but which has not as yet been much cultivated here. Each of these species is 13 to 26 feet high and 2½ feet or more in diameter. They are found in all sorts of soil, particularly in crevices of calcareous rocks. *P. palaestina* is found more frequently than *P. terebinthus*, which seems to prefer moister soils. The former grows in the valley of the Jordan and extends as far as Petra and the Arabah, generally in slightly moist sandstone soils. This plant is especially to be recommended for the vicinity of Indio and Mecca, Cal.

Pistacia atlantica.—This variety has proved to be a good stock for *Pistacia vera* (the pistache), and I believe that *P. terebinthus* and *P. palaestina* will also prove valuable and should be imported and tried in the United States. The male flowers of *P. terebinthus* are often used in Asia Minor for the pollination of *P. vera*, and it may be that in this way we can increase the productiveness of *P. vera* in the United States, where hitherto it has not yielded well.

Amygdalus communis.—The wild almond is very common in Palestine and Syria; that is, a really wild almond, not one that has escaped from cultivation. It covers a very extensive area, and there-

fore a number of varieties and local races have developed. These merit careful study. Some are found in the cretaceous and nummultic rocks of Samaria; others prefer the basaltic hills of Gaulanitis, etc. These wild almonds are plentiful enough to furnish an article of commerce. The Bedouin women of Gaulanitis (Djôlan) gather the bitter almonds and carry them to the market at Damascus. We get wild almonds from the region of Nablus (the ancient Shechem) from which to grow stocks for our nurseries. They are excellent stocks for almonds and for apricots on dry and nonirrigable lands.

Amygdalus orientalis.—I believe that this species is also worthy of being recommended, although I must admit that I have had no personal experience with it. It is common on Mount Hermon, and I know it to be one of our hardiest species. It thrives in crevices of rocks looking toward the east, thus being exposed to the hot, dry winds of the desert. It extends to altitudes of 3,300 to 5,000 feet and is very resistant to the rigorous winters of these high regions. It is therefore one of the best species to test as a stock for poor soil in barren regions. It should prove valuable in Washington, Oregon, and Colorado.

Prunus microcarpa and Prunus ursina.—All that has been said about *Amygdalus orientalis* applies also to *P. microcarpa* and *P. ursina*, which appear in the same localities and under the same conditions. The fruits of *Prunus microcarpa* are slightly bitter but very refreshing, and the writer has often enjoyed them when tired out from long walks in this region. The seed has a thin shell which is easily broken.

Prunus ursina (bear plum) has a globular fruit, violet-red or yellow when ripe, an inch in diameter. It takes its name from the fact that bears, said to be formerly numerous on Mount Hermon, but now exceedingly scarce, are very fond of it. It is also eaten by the shepherds and by the wives of the peasants. It is a bush 6 to 10 feet in height, with a trunk 4 inches to 1 foot in diameter.

Prunus cerasia.—This shrub is very interesting on account of its fruit, which is quite similar to the damson in taste and appearance. The seed, however, is longer and more pointed. The fruit is oval and one-half inch to 1 inch in length. This shrub is cultivated more for stock than for its fruit, which is astringent and not very agreeable. It is possibly the prototype of the cultivated damson. This seems the more probable from the fact that the word "damson" is thought to have been derived from Damascus.

Crataegus.—Among other species of Crataegus the most important is *Crataegus azarolus* with its numerous varieties and races. This is a shrub of the calcareous hills and appears only on very dry lands. If undisturbed it grows as high as 13 to 16 feet, but its branches are generally hacked off for fuel by Arab women or

mutilated by heavy stones thrown by the boys to shake down the fruit. Some varieties of *azarolus* have fruit as large as a large cherry, with a very agreeable acid taste. Although they are sold on the markets of the Orient, they would not be marketable in Europe or America because of the large stones, as in the case of the loquat (*Eriobotrya japonica*); but specimens are often found which are nearly stoneless, and it is possible that this character could be fixed by selection.

For fifteen years or more the writer has used *Crataegus azarolus* as a stock for pears with excellent results. Top-grafted at 2 to 3 feet above the ground, it develops into very beautiful, productive, and long-lived dwarf trees, provided the grafting is done with very early varieties. This shrub occurs in extremely hot, dry places and must therefore complete the greater part of its development early in the season. Its roots, therefore, are unable to furnish the amount of sap necessary to develop pears in August. If, however, it is grafted with a pear which fruits in May or June, when the roots of the Crataegus are in their period of greatest activity, the best results are obtained. I have found this to be true in Palestine, and Mr. Dumont, near Tunis, who has grafted hundreds of wild Crataegus plants, also finds that he is successful only with early varieties of pears.

I may also mention *Crataegus orientalis*, having a large and palatable fruit, and *Crataegus sinaica*. Although the fruit of this species is scarcely larger than a pea, with a dry and tasteless flesh, it will grow on the very driest lands. All of these species of Crataegus are spiny. They are par excellence the stocks for pears on dry lands and calcareous ridges. The writer speaks only of pears, because he has experimented with them, but he sees no reason a priori why these stocks should not do as well for apples, which he has not as yet tried.

Pyrus syriaca.—This wild pear ought to be considered along with the species of Crataegus. It would be adapted to an even greater range of soil, for, though the Crataegus species appear only on very porous soils, some races of these wild pears grow in very humid localities, almost swampy, or at least submerged for two or three months of the year. *Pyrus syriaca* is a shrub 13 to 20 feet high. The branches of young plants and the suckers at the base of the trunks of old trees are very spiny, but there are no thorns at the top. The fruit is a favorite with the peasants and shepherds. It grows, as said, on damp soils at sea level; it is also found in the forests and underbrush on hills and plateaus. Sometimes a single tree stands by itself without any protection from the winds and the burning sun. It grows at 2,500 to 3,000 feet altitude on the Senonian chalks, as well as on the dolomitic and nummulitic limestones of

upper Galilee and also at 3,300 feet and more on the Jurassic beds and the lower Cenomanian sandstones of the slopes of Mount Hermon. It seems to the writer to be a very promising stock. It was in this region that Kotschy found some wild pears, which were so good in flavor that he named them *Pyrus nobilis*.

FRUITS.

In addition to the wild types which are excellent for stock and may yield some valuable results by hybridization and selection, we may note some of our cultivated fruit varieties which would be worth trying in the United States.

APRICOTS.

The almond is generally used as stock for the apricot, except in irrigated orchards such as those in the region of Damascus, where the varieties desired are grafted on "Muschmusch kelabi" (dog apricot, or bitter-seeded apricot). *Prunus spinosa* is rarely used as stock, and then only in northern Syria.

Syria and Palestine have a great number of varieties of the apricot. I have secured from Damascus alone eight varieties for my own use. There is a difference of fully two months between the ripening of the earliest and of the latest varieties in this one place under the same conditions of cultivation. These varieties differ in habit of growth, productivity, appearance, and taste of fruit. Only one variety, "Muschmusch kelabi," has bitter kernels; the kernels of all of the others are sweet and are eaten like almonds. The annual export of "kelabi" kernels from Damascus alone averages 60,000 pounds. Some varieties have especially good shipping qualities. They are packed, without being wrapped, in boxes that have been used for the importation of Russian petroleum. They are carried upon mules, sometimes for two or three days, over precipitous, rocky paths, and yet, in spite of all this and of their being exposed to great variations of temperature, they reach the markets in excellent condition.

Other apricots, like the "Tadmuri" (meaning Palmyrian), though splendid fruits, are not very productive and would not stand the conditions just described.

The "kelabi" is used only for the manufacture of apricot paste. Spread in a thin layer and dried in the sun, it looks like a piece of leather. It is treated with a little oil, so as to prevent its becoming brittle. It can then be rolled up, and, being very easy to carry, it forms an important part of the rations of the Mohammedan soldier. On account of its value to him in his religious campaigns it is called "Kamr-ed-din" (the crescent). This paste is an important

article of commerce, and I shall later write a special article on its preparation and uses. Here I wish only to say that, at my suggestion, some experiments in its manufacture were made during the present year in the Santa Clara Valley, California, and with a gratifying degree of success. It is therefore not impossible that the utilization of "slab" apricots in making this paste may prove of importance, especially during years when there is a large percentage of low-grade fruit. This may result in the establishment of a new industry for the utilization of apricots, the product being shipped to the mining districts.

QUINCES.

The quince is cultivated in different regions and under various conditions of soil and climate. We have some varieties adapted to irrigated orchards only; others that yield fruit on the cool, but dry, plateaus of Samaria. Some varieties have fruit edible when ripe; others are always astringent. All yield a beautiful ruby-colored jelly of a very fine flavor.

POMEGRANATES.

Pomegranates are extensively cultivated in Syria and Palestine, although the crop is not one of great commercial importance. They grow in wild thickets, having escaped from cultivation, and are very drought resistant. Pomegranates are also cultivated in almost all orchards, both with and without irrigation. They comprise two groups, the acid fruited and the sweet fruited. The latter includes those fruits with large, hard seeds and the form called "Malissi," or seedless. As a matter of fact they have seeds, but these are small and thin shelled. There are a great number of races among the "Malissi." The "Bint-el-Bascha" (daughter of the pascha) grows at Gaza, in southern Palestine, at sea level. This name is given by the Arabs to different fruits or products of special excellence. These varieties are found on deep, Quaternary soil and they require irrigation. They have been famous from ancient times and are exported to Egypt and other lands. Er-Reineh, a christian village in lower Galilee, between Nazareth and Tiberias, is also known as Um-er-Ruman (mother of the pomegranate), because so many varieties of such excellent quality are produced there. They grow at 1,000 to 1,300 feet altitude in calcareous soils. The pomegranates of Jericho and the oases are much liked. They grow readily in very alkaline soils.

OLIVES.

We now come to two characteristically oriental crops, grown there for centuries and always of great importance, viz, the olive and the fig.

In spite of all that has been said and written about the Oleastrum, the Zeboudj of the Kabyles (Algeria), the writer believes that it is only an olive escaped from cultivation. The wild olive certainly originated in the hills and mountains of Syria and Palestine, rather than in those of Algeria. At any rate, there are different varieties or races of wild or half-wild olives in our hills adapted to all kinds of soil and to widely different climatic conditions. Though they would not be ranked botanically as varieties, there are three distinct races among our wild olives which are used either for direct planting or in our nurseries.

The first is a form with thin, brittle, blackish bark. This form is not much liked; it is difficult to propagate, grows slowly, is hard to graft, and the fruit produced by these grafts is said to be not very rich in oil.

Second, there is a form with waxy green bark. This is easily propagated, grafts readily, is very much liked, and when used as a stock gives a very large yield of oil, but it is of rather slow growth and it fruits late.

The third form has a thick, white or gray bark, which separates readily. It is particularly well adapted for grafting, is easily propagated, grows rapidly, and fruits early. It is said that the trees of this race do not live as long as those of the preceding one.

All of this information is not guaranteed, as some of it was obtained from the Arabs, but that part which relates to propagation, growth, and grafting is from personal observation.

There is, as is to be expected, a great multiplicity of forms in the cultivated varieties of olives (see fig. 4). In southern Palestine we have olives which grow under much the same conditions as the Chemlali of Sfax (Tunis), the soil and climate being about the same and the rainfall as limited. I may note, however, that the varieties from Gaza, Ramleh, or Lydda, which grow in southern Palestine on Quaternary soil, do not contain the excess of margaric acid which is characteristic of those from Sfax. This is a great defect in those varieties and is the cause of their oil being rated as inferior. To be sure, the oil of southern Palestine is also rancid and mediocre in quality when prepared in the Arab fashion, but excellent when well prepared.

Just as the name "Chemlali" is applied in Algeria and Tunis to several different forms, so also in Palestine the name "Nabali" has a somewhat indefinite use. The Nabali of Et-Tireh, near Haifa, growing on calcareous Cenomono-Turonian formation, and the Nabali of southern Palestine, growing on Quaternary soil, are altogether different. The first is richer in oil and is of superior quality. One form in this locality is particularly in demand because it is more productive and yields more oil, and that also of a finer quality. But we are not

sure that this difference is really one of variety; the superiority is probably due to the soil. The villages of Et-Tireh, Ijzim, and Ain Ghazal (mother of gazelles), in the foothills of Mount Carmel, are renowned for this superior olive. All the trees reported from there were found to grow in rich land made up of volcanic tufa and disintegrated basalts from the old eruptions of the Secondary epoch.

Er-Rameh, in upper Galilee, 1,300 to 2,000 feet in altitude, holds the record for the productivity and quality of its olives. There is here a fair degree of uniformity in the character of the fruit, and the best methods of cultivation in the country are here in use.

A number of other varieties are found in the region of Damascus. The altitude here is 2,000 to 2,300 feet, and the winters are rather

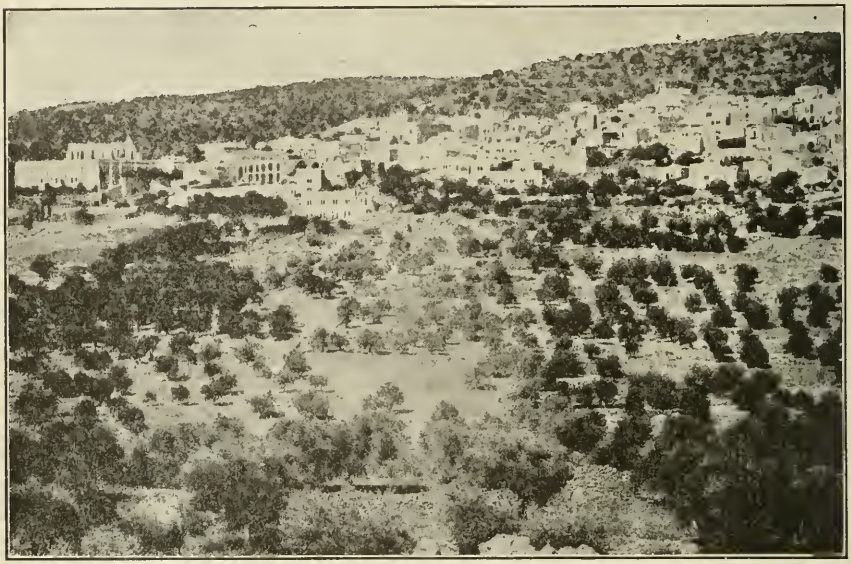

FIG. 4.—Olive groves on rocky soil in the environs of Jerusalem, showing artificial terracing.

severe. Some of these varieties are especially rich in oil; others particularly well adapted for table use. The only one called "Damascus" olive remains green in color until ripe and is preserved simply by means of lye made of ashes. It is often as large as a pigeon's egg, larger than any of the Spanish "aceitunas Sevillanas" or "aceitunas de la Reina" that I have ever seen.

As the winters are mild in the particular regions where I have carried on my work, I have studied the resistance of our forms and varieties in relation to heat and drought rather than to cold. But as there are varieties growing in parts of Palestine where the winters are severe I have no reason to doubt that there are forms among these which will grow well in those parts of California, Texas, etc., where winter temperatures are relatively low. In fact, our olives extend

through a vertical range of nearly 6,500 feet. They grow under irrigation at Abedieh and Jericho; in the valley of the Jordan, at 650 to 850 feet below sea level. They are commonly cultivated at Hermon and at Lebanon, 4,000 to 5,000 feet in altitude, where the winters are long and relatively severe. In upper Galilee—in the region of Safed, for instance—at an altitude of 2,000 to 2,500 feet, it is claimed that low winter temperatures increase the olive crop; for it is stated that whenever the winters are cold (that is, the temperature reaches 14° to 18° F.) the crop is always abundant. If this generally accepted opinion is true the increased production is to be attributed, according to my opinion, not to any beneficial effects of cold upon the tree but to the fact that such low temperatures probably kill most of the parasites, particularly the olive scale (*Lecanium oleae*). This is very prevalent and the people know no way of combating it.

FIGS.

Though the fig is not cultivated to so great an extent in Palestine as in Smyrna, it is, nevertheless, a very important crop, particularly in upper Galilee, where the population is very dense and labor is cheap. There are a great number of varieties there—some with black fruit, others with green, and still others with pink. Some of these figs can be used only while fresh. These are not very extensively cultivated, there being practically no shipping facilities. Other varieties are dried and pressed and, to some extent, shipped abroad. They are, however, chiefly consumed by the Bedouins, whose liking for "kutteins" (dried figs) is proverbial. These people are not at all critical, so that no effort has been made to improve the methods of preparing this product or to study the best varieties for cultivation.

It is our wild figs, however, rather than our cultivated varieties, that will probably prove of the greatest value in the United States.

Ficus carica.—This species and its numerous varieties grow wild abundantly in the crevices of rocks. The openings of the numerous mountain caves are generally shaded by these wild trees. In the valley of the Jordan, in the neighborhood of Fusail, there are patches of humid soil, of a black color generally, characteristic of the injurious carbonates. The wild figs nevertheless grow there, showing that they are particularly resistant to alkali. This fact should make them a valuable stock in California. The Smyrna fig has been established in California, but this variety does not show a great degree of resistance to alkali. I firmly believe that the local races growing in Palestine on alkaline soils will be of great value as stocks to the fig growers of California. I say "races" rather than "varieties" because the use of this latter word has been so much abused by some authors.

Ficus pseudo-sycomorus.—This species is not very abundant. It grows on the edges of cliffs and at the entrances of caverns in the desert, and it is especially resistant to drought and alkali. I do not know that it has ever been tried as a stock, but I do not hesitate to recommend it for introduction and experiment.

Ficus sycomorus.—This tree (see figs. 5 and 6) deserves our attention. It is a native of India and grows all along the Palestine coast as far north as Beirut. It is very drought resistant, and in southern Palestine grows to a considerable size. Its wood is highly valued on account of its great density and the size of the trunks. It is used particularly to make sledges for thashing. But it is the use of the fruit as forage which should make it of value for certain parts of the United States. Although it is of inferior quality, it is greedily eaten by the Bedouins. The tree yields very abundantly, the fruit covering all of the old branches and even the trunk. It has several successive flowering periods, and the Arabs say that the "Djemeiz" gives seven harvests a year. The quantity of fruit yielded by a single tree is simply incredible, and the fruit, which is tolerably rich in sugar, would be in arid regions an excellent food supply for sheep and hogs. The tree grows well on dunes.

FIG. 5.—Fig tree (*Ficus sycomorus*) near Jaffa, showing its unusual resistance to drought. The roots are laid bare by the wind, and the branches on the windward side are checked in development by constant and strong sea breezes.

DATES.

At the present time date cultivation in Palestine is not of any great economic importance. But this has not always been the case. In biblical times Jericho, in the valley of the Jordan, about 600 to 700 feet below the level of the sea, was called the "City of Dates." At the beginning of the Christian era, when Tiberias and its environs were the Riviera of that time and when the princes and princesses of the Orient went there to spend the winters, the city of Magdala was celebrated, not only for its establishments for cleaning and dyeing the valuable costumes of its noble visitors, but still more for the delicious early dates which it produced.

To-day the cultivation of the date in the valley of the Jordan is of no importance whatever. Only the village of Abadieh still has a

few date trees of a local variety, the fruit of which is of good quality. But the people who are establishing new plantations, instead of propagating this local variety, prefer to send to Egypt or Bagdad and bring from a distance and at great expense plants which are really of less value than the local product.

There are two places, however, where the old date plantations have not entirely died out. The first is east of the Dead Sea in the Valley of Zerka Maain, the ancient Calirrhoe, once celebrated for its hot baths, frequented by King Herod. Here thousands of date trees grow wild in crevices of arid sandstone 600 to 800 feet below sea level, in narrow gorges intensely hot and dry, where the soil is extremely alkaline.

The second place is farther north, in the valley of the ancient Hieromax, 500 to 600 feet below sea level, in a marsh formed by several hot springs, with a temperature of 118° to 133° F. Here these wild dates form a veritable jungle, probably one of the few places of its kind in the world.

FIG. 6.—Fruit of fig tree (*Ficus sycomorus*). The Arabs in Biskra and Egypt cut off the tips of the immature figs in order to make them ripen. Three days after this is done the cut figs become twice as large as those uncut and develop a much better taste. The fruits marked "*I*" have been cut.

The historical accounts which vouch for the quality of the dates produced in these regions furnish proof that the cultivation of this fruit can be made profitable in such localities, and we may reasonably expect that the variety found in and around the valley of the Jordan may be of value for certain similar localities in the San Joaquin Valley.

Along the coast of Palestine, in sandy soils and on the edges of dunes, the date is here and there cultivated, especially in irrigated orchards and gardens. The ordinary varieties, however, do not ripen without artificial aid, and to this end the Arabs wrap the bunches of fruit in cloths soaked in vinegar. These cloths are kept constantly

moist. When the wrapping of the fruit is discontinued the dates have changed from a black or chocolate color to an amber-yellow and have lost their astringent taste, the tannin having probably been rendered insoluble by the acetic vapor.[a]

It is probable, as suggested by Mr. Fairchild and Mr. Swingle, that the Japanese method of artificially ripening persimmons by putting them in barrels that have contained "saki" is based on this same principle, and that the astringency of the fruit is overcome in this case also by acetic vapor.

GRAPES.

Though the religion of the Mohammedans forbids the use of wine, they cultivate grapes extensively and have developed a great number

FIG. 7.—Commercial grape nursery at Hedera. The workmen, Russian and Koordistan Jews, can understand each other only in the Hebrew language.

of varieties. (See fig. 7.) Before the German and Jewish colonization began in Palestine, grapes were cultivated chiefly for table use and for raisins.

For the most part the Mohammedans have propagated varieties that are not very juicy, having hard flesh and strong skins, as the

[a] When I visited Tucson, Ariz., on September 27, 1909, I had the pleasure of explaining this process to Doctor Vinson, of the University of Arizona. He began immediately to experiment along this line, and I am very much gratified with the success secured by him. See report of his experiments in Science, n. s., vol. 30, no. 774, pp. 604–605. I believe that this process of artificial ripening ought to be experimented with in other States where, as in Arizona, there is difficulty in getting certain varieties of dates to ripen.

fruit often has to be carried for days on the backs of donkeys or camels before it reaches its nomadic consumers or the people of far-distant villages. Our varieties are therefore rather distinguished for size, richness in sugar (habitually more than 18° Bé.), and good shipping qualities than for fineness of flavor. The grapes not eaten fresh are made into raisins, and the vicinity of Hebron, near Jerusalem, and more particularly of Es-Salt, in the Trans-Jordan, are the great centers of raisin production, producing about a hundred thousand dollars' worth every year. These places are at an altitude of more than 2,500 feet, and the grapes are grown on calcareous hillsides of Cenomanian and Senonian formation.

A study of the vineyards of Palestine would no doubt reveal many varieties that would be valuable to the United States. Mr. George C. Husmann, Pomologist in Charge of Viticultural Investigations, Bureau of Plant Industry, says that among the hundreds of table varieties with which he has been experimenting for years he considers the Palestinian "Dattier de Beirut" the best white grape and the "Purple Damascus" one of the best black varieties. And yet neither of these is among our finest Palestine sorts.

FIG. 8.—Seedling orange trees at Hedera, grown with a view to originating new varieties.

JAFFA ORANGES.

All of the crops mentioned have been cultivated for centuries in the Orient, but oranges were introduced there at a relatively recent date. (See fig. 8.) Hasselquist, a pupil of Linnæus, who was the first naturalist to study Palestine, in the middle of the eighteenth century, speaks of the beautiful gardens of figs and pomegranates at Jaffa, but has not a word to say about oranges. This silence is significant. But at the time of Napoleon's Egyptian campaign, at the close of the eighteenth century, the orange was mentioned among the fruit trees. Chateaubriand, who traveled in the beginning of the nineteenth century, also speaks of this fruit. Lamartine, visiting Palestine in

October, 1832, praises the beauty and quality of the Jaffa orange, but speaks of having seen the flowers and the golden fruits at the time of his visit. Now, at this season of the year it was too late for the trees to have been in bloom and not late enough for the fruits to be ripe. This and other errors of observation cause me to doubt the value of the poet's description from the point of view of the naturalist and agriculturist, although its value as literature is unquestioned.

At any rate, in the second half of the nineteenth century the Jaffa orange was known in the markets for its superior quality. It was exported by sailing vessels all along the Syrian and Egyptian coasts. Its thick skin made it a good shipper, and it was carried as far as Constantinople and into Greece. It was not until 1875 or thereabouts that it was exported to England, while to-day Liverpool alone takes about 500,000 to 600,000 cases of the 700,000 or 800,000 that are annually exported.

I have not been able to learn the origin of this variety, which is cultivated only at Jaffa. In form it is very similar to the Malta orange, and it is possible that it is remotely descended from that variety; but it is not a blood orange, despite its marked affinity to that group.

The Jaffa orange is one of the largest, larger even than the Washington Navel. Its form is obovate, its skin very thick, and its fruit seedless. The tree is not spiny, and the fruit, therefore, is never scarred. Its shipping qualities are excellent. It is packed with very little care as compared with the methods used in California. The cases are thrown violently into the steamers, and they are often carried for three weeks without refrigeration and subjected to the greatest extremes of temperature; and yet the oranges reach the English markets in good condition and command good prices. It is at least a month from the time they are picked until they are purchased by the wholesale dealer, and during all of that time they are without cold storage.

Not only is this orange peculiar to Jaffa, but peculiar methods of cultivation and peculiar stocks are there in use.[a] The Schamouti, as the Jaffa orange is called, is generally grafted on a special sweet lime, which I have not found either in Africa (Algeria and Tunis) or in the United States. It is sometimes, though more rarely, grafted on the bitter orange (*Citrus aurantium*). This is not so well liked, because it requires more irrigation and is later in fruiting.

I must add that the Jaffa oranges which I saw in Tunis and Algeria and those grown in America and illustrated in American publications

[a] See Aaronsohn and Soskin, Die Orangengärten von Jaffa, Der Tropenpflanzer, Berlin, 1902.

have very little resemblance to the real Jaffa orange. They are represented as having seeds, while the true Jaffa orange is seedless.

Saida, the ancient Sidon, is another center of orange production. Many different stocks are used, and several varieties of oranges are known. Two of these are blood oranges, one called "Damaoni" (blood) and the other "Hutmali" (meaning "ringed," because it has a ring around the base). These two varieties are very popular. The "Beledi" (seedling) is also grown. This commonly yields three thousand fruits to the tree, and sometimes as many as five thousand.

FORAGE PLANTS.

Stocks and fruit trees are not the only interesting things in the Palestine flora. It contains some very valuable forage plants. This may seem to be strange in a country which suffers from a lack of forage, but this is due to the fact that the people do not cultivate the plants they have at hand.

The Leguminosæ must be considered first. In this family we find one of the most valuable forage plants in existence for semiarid regions, the importance of which for this purpose has not been sufficiently appreciated. This is the carob tree, sweet-pod, or St. John's bread (*Ceratonia siliqua*).

The carob tree is not, properly speaking, a native of arid, desert regions. It grows 20 to 25 feet in height, with a trunk as much as 40 inches in diameter. A tree 25 to 30 years old yields about 450 to 550 pounds of pods. I have seen wild stock, 15 or 18 years after grafting, that yielded 900 to 1,100 pounds of pods in good years, although a good average is 450 pounds to the tree. Counting twenty trees to the acre, this gives more than 8,000 pounds of pods to the acre. The pods contain 40 per cent of sugar—even more in good varieties—and 7 to 8 per cent of protein, so one can readily see why we rank it at the head of all forage plants.

An acre of carob trees upon arid soil yields a much greater quantity of food matter than an equal area planted with the best alfalfa. The food value of the carob has been known for a long time. It is the basis of the fodder of the English cavalry horses at Malta and of the horses belonging to the tramway company of Naples. It is among the chief exports from the island of Cyprus, and the growing of carob trees is one of the best sources of income on the island, for, once started, the tree continues to yield for many years. In this respect it is similar to the olive, which grows in the same localities, but it is generally admitted that the carob can not stand so arid a soil as the olive, as it requires more moisture in the subsoil. However, on this point also there are differences between the local races, there being some which will stand a considerable degree of aridity. There are several wild

carob races and a few cultivated ones that should be tested by the Bureau of Plant Industry.

There are few crops so well adapted as the carob to agricultural conditions in certain parts of the United States. The tree demands little care, requires almost no pruning, does not need to be cultivated frequently, and has not so far shown any disease demanding treatment. It seems to me to be the ideal forage plant, as it gives a high yield with very little labor. It should succeed in California and in parts of Arizona and Texas.

There are many of our Leguminosæ that should prove very interesting. We shall probably learn to value many species found among the Galegeæ and Loteæ, and in the genera Vicia, Hedysarum, and Trifolium. For the sake of brevity I shall mention only one species.

There are good reasons for believing that berseem (*Trifolium alexandrinum*) originated in Palestine, though we do not know definitely where it was first cultivated. But it grows wild there, as does also *Trifolium carmeli*, which differs from it only in slight botanical characters. Moreover, *Trifolium panormitanum* and *Trifolium supinum*, very closely related to *T. alexandrinum*, grow wild in Palestine. The fact that this whole group of closely related species grows wild in this region seems to indicate that they originated here. At any rate, the cultural value of these species needs to be studied.

Though berseem is a very valuable local plant, it is little cultivated by the natives, being grown chiefly by German and Jewish colonists. It is sown with barley in the autumn along the coast, where the rainfall is as low as 14 to 16 inches per annum. It is of course grown without irrigation and gives two cuttings in the spring. In some very rainy years berseem yields three cuttings, or at least a good aftermath following the second cutting. After being pastured, the berseem is plowed under and forms an excellent green manure for a succeeding cereal crop. Egyptian berseem, grown under the same conditions of soil and climate, was found to be not nearly so good as our native races, and the latter should be carefully studied with a view to introduction.

I wish also to mention the Palestine saltbushes for alkaline soils, particularly *Atriplex palestina* and *A. halimus*, as well as *A. leucoclada*. The last grows from 3 to 6 feet high, but is so eagerly browsed by sheep and camels that it is difficult to secure even good herbarium specimens.

ANNUAL CROPS.

The greater the number of crops a farmer has, the greater the possibilities of crop rotation. Moreover, under such conditions he can farm with less risk than if he cultivated only a few crops and can make better use of his workmen, animals, machines, etc. So I

think it is worth while to mention two crops practically new to the United States, the chick-pea or garbanzo (*Cicer arietinum*) and the sesame (*Sesamum orientale*).

THE CHICK-PEA AND THE SESAME.

Chick-pea.—The chick-pea (fig. 9) is one of the most valuable legumes grown in Palestine. It does not demand such careful prep-

FIG. 9.—Branch of plant of chick-pea (*Cicer arietinum*), showing pods and white flowers. The variety with rose-colored flowers has black seeds, which are not so well liked as those of the white-flowered variety.

aration of the soil as sesame, and in good years it yields 12 bushels to the acre. It sells for as much as wheat, and often for more. It is therefore a remunerative crop and is excellently adapted for use as a rotation crop before wheat.

There are several sorts of chick-peas to be considered. Those of southern Palestine are different from those of central Palestine, and the plateaus of upper Galilee and farther north produce still different types. In the southern part of the country the chick-pea does well with a rainfall of 16 inches or even less. I know from personal experience that these races do not grow well under irrigation. On the other hand, in the north there are races growing at 4,000 to 5,000 feet altitude, where the yearly rainfall is as much as 40 inches, which are nevertheless liberally irrigated with water derived from the melting snows of Mount Hermon.

As there are in Palestine no bean harvesters like those used in the United States, chick-peas are gathered by hand, the plants being pulled up by Arab women. The stems of this plant growing in southern Palestine are very corrosive and attack the hands of the workers. I have thought that it would be a good idea to introduce cultivated varieties from the Crimea and the Caucasus. These have erect stems, so that they can be harvested with mowers; they have scarcely any corrosive quality and could be harvested by hand, but can not resist drought. The leaves and stems of the Palestine chick-pea are corrosive because they are covered with crystals of oxalates and other hygroscopic salts which probably absorb to some extent the moisture in the air; so, no matter how dry the night may be, a field of chick-peas always glistens with drops of water in the morning. Is it this condensation of atmospheric humidity which enables the plant to resist drought, while the Russian plant, not provided with this means for obtaining moisture, does not grow at all or gives a poor yield?

The importance of choosing a race may be illustrated by another example. Some years ago a little Jewish colony was founded south of Tiberias about 650 to 800 feet below sea level. The soil was a gypsum marl, the annual rainfall about 1⅓ feet. The Arabs had cultivated only winter cereals, such as wheat and barley, asserting that no summer crop could grow there without irrigation. They cultivated chick-peas at Tiberias, but only in kitchen gardens. These latter were sown in winter in well-sheltered places, so as to profit by the winter rains. They came from Safed, scarcely 12 miles away, a locality with twice as much rainfall and 3,300 feet higher in altitude. I advised my brother, established in this colony, to try a variety of chick-pea not so well liked as that from Safed but coming from a place where the conditions were more like his own. The success of the first year surpassed all expectations. The neighboring colonists, seeing this, hastened to plant large areas with this chick-pea. I feared that they were planting on too large a scale and tried to prevent their doing so. But their experiment was so successful that the chick-pea is now one of the common crops of this colony, and

every year some hundreds of acres are sown in this locality where five to seven years previously its cultivation was considered impossible.

The chick-pea will, I think, do well in the dry-farming regions of the United States, and if its cultivation is properly developed it should become a more important crop than the Lima bean.

Sesame.—The sesames of Palestine are of most excellent quality. In the markets of Marseille and of Germany they pay a special price for the Haifa sesame. This is preferred to the sesame of Jaffa or the Ghor (the Arab name for the valley of the Jordan), for at Haifa, as we shall see, a local race has been developed under quite different conditions.

The soil must be well prepared for sesame. For the best results it should be pulverized until "as fine as ashes." Sesame is generally sown about the time of the barley harvest—that is, about the end of April or the beginning of May, after the rains have stopped—for the Arabs have noticed that sesame germinates very irregularly if rain follows immediately after the sowing. They explain that this is because the oil in wet seed becomes rancid and therefore prevents germination. Although they have observed the fact correctly they have assigned a wrong interpretation. The real reason is that as after a rain a crust forms over the pulverized soil, the feeble sesame plants are not strong enough to break through it, so that the stand is irregular and too sparse. The Arab, who knows nothing about harrowing, does not know how to break up this crust. By harrowing we were able to sow sesame earlier and thus to have the benefit of the last rains. However, although the Arab tries to sow his sesame only after the rains, it grows as it gets sufficient moisture from water stored up in the soil.

South of Jaffa, where the rainfall is not more than 14 to 16 inches, the sesame is grown upon sandy clayey soils. At Haifa the rainfall averages more than 24 inches and sesame is grown on rich ground of volcanic origin, so that a very different race and one of a much better quality is developed there. In the valley of the Jordan the situation is still different. There, after barley or wheat has been harvested and the ground copiously irrigated, the sesame is sown on well-prepared soil. It grows without any further irrigation, under a torrid sun and in an alkaline soil, but here the reserve of water stored up in the soil is greater than at Jaffa or Haifa. We see, then, that under different conditions local races adapted to such conditions are developed, and this indicates to us how much care and study is necessary when we introduce new plants into strange surroundings.

I do not believe that under present labor conditions sesame can be profitably cultivated in the United States, because the plants of the crop do not all mature at the same time. This makes necessary

several harvestings, always by hand. With the prices for labor now prevailing in the United States this would not pay. But, by means of methodical selection, uniformity in the germination and maturing of these plants could easily be obtained.

I believe, therefore, that the chick-pea and the sesame deserve to be introduced into the semiarid regions of the United States and that they will furnish valuable aid to the farmer in the rotation of crops.

CEREALS.

Barley.—After having discussed the number and value of the local races in other crops, little remains to be said regarding barley and wheat. There are, of course, in Palestine a great number of varieties of these grains. There are barleys belonging to the three botanical species *Hordeum distichon*, two-rowed barley; *Hordeum vulgare*, ordinary six-rowed square-headed barley; and *Hordeum hexastichon*, the true six-rowed or club barley.

The species most extensively cultivated is *Hordeum vulgare pallidum*. Gaza barley belongs to this variety. It is cultivated in southern Palestine on lands of Cenomanian or of Pleistocene origin and where the annual rainfall is often not more than 10 or 12 inches. It is much used for brewing in England. More than a million dollars' worth is exported annually.

The barley of the Ghor or that of the Jordan is heavier and has the more regular grains characteristic of *Hordeum hexastichon*, the true six-rowed barley. It is a barley adapted to arid regions and to alkaline soils. The barleys cultivated on the vast steppes around Damascus belong principally to *Hordeum distichon*, or two-rowed barley.

Wheat.—Though the greater number of the cultivated wheats of Palestine belong to the group *Triticum durum*, this is not the only group represented. Some belonging to *T. aestivum* and to *T. turgidum* are cultivated, especially in the northern part of the country. There are a great number of kinds of *Triticum durum*. At the little market of Haifa there are five or six different races. I shall mention only the "Nursy," the "Zeriin," and the "Dalaika," named after the villages which produce them.

The first has a long and rather thin grain and is splendidly adapted to low, humid, almost marshy soils. The wheat of Zeriin has a large, full, white grain and is adapted to the hills of the Senonian limestone formation. The wheat of Dalaika has a small, translucent grain. It is a favorite in the markets and grows on soil of volcanic origin, which is very fertile but subjected to such intense sunlight that no other variety can stand it.

Now, the three localities mentioned are hardly 10 miles from one another, yet each one has its special race. What is the significance

of this fact? From the physical and geological nature of Palestine, as has been explained in the introduction, there necessarily resulted a diversity of climates within a very small area, and this diversity of both soil and climate has given rise to a very rich and varied flora and fauna. In the cultivated plants a multiplicity of forms has also been favored by the political as well as by the natural conditions. The country has for centuries been divided among a number of hostile tribes, each one living in a territory of quite definite natural boundaries. The hostility of these neighboring tribes was so great that nearly all commercial relations were destroyed, the only interactions being those of warfare. Access to the markets was thereby cut off, and the Arab learned to depend entirely upon the products of his own immediate district. As the same products continued to be cultivated for centuries on the same soils without outside introduction, local races were necessarily developed. These conditions, which lasted for more than ten centuries in the Orient, are finally rapidly disappearing.

From a human point of view we have every reason to rejoice at the pacification of the Orient, because of the greater safety to life and property and the better intercourse it has brought about; but from the standpoint of the cultivation of plants we are losing ground, for it is a natural tendency to reject all of the old habits and in so doing to annihilate many of these local races which have been in process of development for so many centuries. This can best be illustrated by the following example:

When the Jewish colony of Yemma was established at Dalaika, the colonists, who had no feeling of prejudice or hostility toward the Arabs of Nursy and Zeriin, thought it would be an improvement to give up the small-grained Dalaika wheat and to introduce the fine, large-grained wheat from Zeriin. The result, of course, was a failure, because the wheat introduced was not adapted to local climatic conditions. Instead, however, of correctly interpreting their failure, some of the colonists attributed it to the use of European plows, and others to American harrows, both of which had been recently imported. (See fig. 10.) I enter into these details in order to show the value of the local products which the Orient has developed during the centuries of stagnation, and also to point out the danger of the destruction of these races of plants in consequence of the general leveling which is a necessary accompaniment of national awakening and progress. An early botanical-agronomic exploration of the Orient is therefore necessary. The sooner it is made the greater will be the chances for obtaining valuable races of plants.[a]

[a] The importance of this point has been emphasized by A. F. Woods. See Science, n. s., vol 26, no. 669, pp. 541–543; also Report of the National Conservation Commission, vol. 3, 1909, pp. 146–150.

MEDICINAL AND MISCELLANEOUS PLANTS.

In the preceding pages I have referred only to crops which can be extensively cultivated and promise to be of considerable economic importance. But there is a host of plants of secondary importance which ought also to be mentioned.

For example, in the Cucurbitaceæ we cultivate *Cucumis melo*, *Citrullus vulgaris* (watermelon), *Cucumis chate*, and *C. melo dudaim*.

Of the different races of watermelon cultivated in Palestine I shall mention only two. The "Abu-taba" (father of the ring), so called because of the large scar which it has in the place of the pistil, is cultivated chiefly along the coast in the neighborhood of the Jewish colony Hedera. It is exported to the value of $200,000 annually (see fig. 11), chiefly from Cæsarea and Minet Abu-Zabura. The

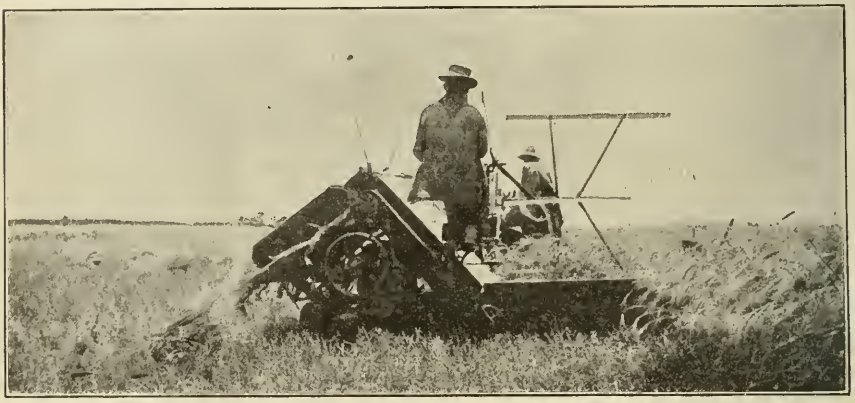

FIG. 10.—An up-to-date Jewish farmer in the dry-farming region of the Jordan Valley using an American-made binder.

latter is a temporary harbor maintained only during the shipping season of these melons. This Abu-taba, which grows on the poorest soil, is very early, and because of its thick rind it is uninjured by journeys of two to three weeks. It is therefore shipped to Egypt, Smyrna, and Constantinople.

Another rather curious sort is that cultivated in the neighborhood of Tiberias. It is not so early as the one just mentioned and does not have such good shipping qualities, but it is much liked on account of the sweetness of its fruit. It is very small, being only about the size of a grapefruit.

There is a kind of muskmelon, cultivated chiefly by the Bosnians in Cæsarea, that is kept until late in the winter. It is, I believe, derived from the sort cultivated at Kirk-Agatch, in Anatolia, a variety propagated in California under the name "Casaba."

I may also mention *Citrullus colocynthis*, a medicinal plant. The fruit grows wild and is gathered for export, chiefly to the United States. The region in which it grows best is a sandy desert between Gaza and El-Arish.

There are other wild plants useful as vegetables, etc.; for instance, *Gundelia tournefortii*, the "Akub" of the Arabs, which grows wild in rocky localities. Its white, juicy shoots are gathered by women and eaten like artichokes. Cargoes of this plant are shipped along the coast from the rocky regions around Haifa, particularly to Beirut. It is a very good vegetable and worthy of recommendation. Its leaves are somewhat spiny when fully developed, but by selection this slight defection could easily be overcome.

FIG. 11.—The watermelon market at Jaffa.

I may also mention the wild *Cynara syriaca* and *Cynara auranitica*, closely related to the cultivated artichoke. The former grows in the damp soils of the low plains along the coast; the latter in the deep, dry soils of the high plateaus of the Trans-Jordan. Their improvement and their use for crossing are to be recommended.

Among the plants particularly adapted to desert regions is *Tamarix articulata*, the "Athl" of the Arabs. Its galls are used for tannin. It grows well in sand dunes and has been successfully cultivated in southern Tunis. This tree is easily propagated by cuttings and appears to me to be well adapted to the southwestern United States.

Another desert plant, *Calligonum comosum*, resembles *Zizyphus lotus* in its habit of growth. It is even more useful than the latter for the fixation of sand dunes. It sends out roots 65 to 100 feet

long, just beneath the surface of the ground. These roots form large nodules, probably because of the sting of an insect, though this matter, so far as I know, has not been studied. These nodules are tolerably close together and like knots in cords, thus making the shrub very valuable in the fixation of dunes. A related species, *Calligonum caput-medusae*, has been used with remarkable results in the fixation of dunes from the Caspian Sea to Turkestan.

It is not my intention in this bulletin to give a complete list of the plants which it would be advantageous to import from Palestine. I wish simply to give a few examples to illustrate the interest that Palestine and the surrounding countries, Arabia, Syria, Mesopotamia, and Anatolia, should awaken in the United States. These countries have been centers of cultivation for many centuries and contain products of great importance to the progress of agriculture, both in their wild types and in the cultivated forms in which they have been grown from time immemorial.

WILD PROTOTYPES OF WHEAT AND OTHER CEREALS IN PALESTINE.

HISTORICAL INTEREST OF WILD WHEAT.

Thirty years ago De Candolle[a] said that the question of the origin of cultivated plants was of importance not only to agriculturists and botanists but to historians, philosophers, and all who are interested in the birth and development of civilization. The fathers of history, Herodotus, Homer, Diodorus of Sicily, and others who lived in the age when mythical deities ruled the minds of the people, always attributed to some god the task of having taught men the uses of plants. At one time and in one nation it was Isis and Osiris; at another, Ceres or Demeter of Triptolemus; but never a thought was given to man's own ingenuity or to his own need as the reason for cultivation. This shows that the cultivation of plants goes back to very ancient times, for when these legends were formulated all recollection of the real origin of cultivation had long since vanished.

As the races developed, the love of legend was replaced by the desire for truth, and in the beginning of the nineteenth century the study of natural science had advanced to such a stage that people demanded facts based upon scientific observation. So we find Link, in 1816,[b] and Dureau de la Malle,[c] in 1826, writing on "The Ancient

[a] De Candolle, A. Origin of Cultivated Plants.

[b] Link, H. F. Ueber die aeltere Geschichte der Getreidearten (Vorgelesen den 20 Marz, 1817), in Abhandlungen der Akadamie der Wissenschaften zu Berlin aus den Jahren 1816–1817, Berlin, 1819, and November 9, 1826, Berlin, 1829; and in "Die Urwelt und das Alterthum," erlautert durch die Naturkund, 2d ed., pt. 1, Berlin, 1834.

[c] De la Malle, Dureau. Annales des Sciences Naturelles, ser. 1, vol. 9, Paris, 1826, pp. 61–82.

History, Origin, and Fatherland of the Cereals, Particularly Wheat and Barley." These scholars seem to have been the first to realize that scientific study was necessary to the solution of the problem and that historic and linguistic data could not be accepted if at variance with the botanical and geographical knowledge of their own time.

These men did excellent work, having a definite understanding of the question and using exact scientific methods. But, as Dureau de la Malle himself said, they could only set forth the probable facts in the case. In order to have positive proof they would have had to present wild individuals of every species under discussion and to prove that they really were wild.

Now, this seemed to be impossible, at least in regard to wheat; for it and the other cereals " do not perpetuate themselves in a wild state when they escape from cultivation." The Count of Solms-Laubach ten years ago[a] declared that the genealogical record of wheat had disappeared forever and that its life history could be rewritten only by hypothesis. Although we knew congenerous wild species of barley, rye, and oats that might reasonably be considered as the prototypes of the cultivated species, we knew of no such wild species of wheat. It had been generally admitted that *Hordeum spontaneum* (*H. ithaburense*) was the wild form of *H. distichon*, or two-rowed barley, and that *H. vulgare*, the common six-rowed square-headed barley, and *H. hexastichon*, the true six-rowed barley, were derived from this species. *Secale montanum*, likewise, was considered the prototype of cultivated rye (*Secale cereale*) and *Avena fatua* or some other wild Avena the progenitor of cultivated oats. But no one knew anything about the original wild form of wheat.

At one time, about the middle of the nineteenth century, it was thought that this much sought for wild form had been found in the neighborhood of Montpellier, France. It was then that the so-called *Aegilops triticoides* was first found in a wild state. It was later produced artificially by crossing *Triticum ovatum* (*Aegilops ovata*) and *Triticum aestivum* (in this case Touzelle wheat). But the researches and memorable publications of Fabre, Godron, Jordan, and others proved that this was not the desired prototype, and the assumption that the cultivated wheats were derived from Aegilops has long ago been abandoned by botanists. It is therefore to be regretted that it has recently been reprinted by certain agronomists in their treatises on the cereals.

DISCOVERY OF WILD EMMER, AND KÖRNICKE'S THEORY REGARDING IT.

Although, as we have seen, almost all botanists agreed with Solms-Laubach when he declared that the prototype of wheat could never

[a] Weizen und Tulpe und deren Geschichte. 1899.

be discovered, there was a small group of the most distinguished botanists who maintained not only that such a prototype existed but that they already had it in their possession. In 1873 Körnicke, when preparing the notes for his standard work on the cereals,[a] had discovered in the herbarium of the National Museum of Vienna, among the stems of *Hordeum spontaneum* which Kotschy had gathered at Rasheyya, on the northwestern side of Mount Hermon, in 1855, part of an ear of a graminiferous plant which he considered to be a wild wheat and which resembled the emmer (*Triticum dicoccum*). But, with an unaccountable forgetfulness, Körnicke did not speak of this discovery in the work mentioned, which appeared in 1885, and it was not until 1889, at a meeting of the Society of the Lower Rhine and Westphalia, that he reported his discovery.[b] At that time he named Kotschy's plant *Triticum vulgare dicoccoides* and declared it to be the prototype of the cultivated wheats. Afterwards Körnicke returned repeatedly to the discussion of the question, urging all botanists who went into the region of Mount Hermon to give their attention to the subject and trying to induce the scientific academies of Vienna and Berlin to organize an expedition for that purpose. His efforts, however, were in vain.

In 1902 Ascherson and Graebner published their "Synopsis of the Middle European Flora." In this work, in the monograph dealing with the Tritici, they set forth Körnicke's views, which thus reached a large public. In order to understand why Körnicke believed that Kotschy's plant represented the wild prototype of wheat, it is necessary to know something of the conclusions he had reached regarding the classification and development of the genus Triticum, which includes wheat and several closely related grasses.

BOTANICAL CLASSIFICATION OF WHEATS.

In the work just mentioned, which adopts the excellent classification of Körnicke in its essential features, but also takes into account the investigations of Hackel, the wheats are classified as follows:

In the section Eutriticum there are three species—*Triticum monococcum* (einkorn), *Triticum polonicum* (Polish wheat), and, thirdly, a collective species, *Triticum sativum*.

Triticum sativum is divided into three small species:

Triticum dicoccum (emmer).
Triticum spelta (spelt).
Triticum tenax (common wheats).

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[a] Körnicke and Werner. Handbuch des Getreidebaues. 1885.

[b] Verhandlungen des Naturhistorischen Vereins der Preussischen Rheinlande, Westfalens, und des Regierungs-Bezirks Osnabrück. Bonn, 1889.

One of these, *Triticum tenax*, is in turn subdivided into subspecies:

- *Triticum vulgare* (wheat). [*Triticum aestivum.*]
  Triticum compactum (short-eared wheat, club wheat).
  Triticum turgidum (Poulard wheat).
  Triticum durum (durum wheat).

This classification is essentially artificial, and the distinctions between the groups are very difficult to maintain. Near the close of Körnicke's life, after having made a specialty of this study for forty years, he declared that it was almost impossible to distinguish between some forms of *Triticum durum* (subspecies of *T. tenax*) and *Triticum dicoccum* (small species of the collective species *sativum*).

The behavior of crosses and hybrids also indicates a very close relationship among the so-called species. Thus, Vilmorin crossed *Triticum aestivum* and *T. durum* and obtained a *T. spelta*. *Triticum polonicum* occupies a somewhat unique place on account of its long glumes, but it hybridizes with the other species and is regarded itself as only a hybrid. *Triticum monococcum* alone holds a place entirely distinct from all of the others because of its refusal to hybridize with the rest. In fact, all of the other species pass so gradually into one another that it seems more than probable that all of the wheats belong to one species.

THE BRITTLE RACHIS OF THE PRIMITIVE CEREALS.

What can we suppose the prototype of wheat to have been, and by what characters can it be recognized? A fragile rachis was undoubtedly one of the characters of this wild prototype. All who have studied the question agree as to this. All agronomists and all botanists regard a rigid rachis as an acquired characteristic, developed by man under cultivation and having a tendency to destroy the plant's natural capacity for dissemination.

All of the genera and species related to wheat, as Aegilops, Agropyron, etc., have this fragile rachis, a necessity in order that the grain be assured a wide dissemination. It is also needful that the grain remain fixed in its glumes as a general protection against premature germination, decay, and destruction by enemies. But this characteristic, so useful to the plant itself, was a drawback to its use by man. Wheat with a brittle rachis requires to be harvested before complete maturity and is difficult to handle. Moreover, grains that are held too closely in the glumes can not be thrashed with flails, but a special system of mills must be used. In Egyptian tombs 6,000 years old have been found heaps of emmer hulls, a careful inspection of which clearly indicates that they were thrashed by such mills, so that their use must date from the most ancient times.

Wild wheat, the same as wild oats and wild barley, must have been provided with the means for ready dissemination. Man, however,

naturally wishes to develop forms which are not so difficult for him to handle, and along this line he has succeeded in obtaining a rigid rachis in barley as well as in wheat. An important difference between the cultivated two-rowed barley (*Hordeum distichon*) and the wild barley (*Hordeum spontaneum*) is the fragile rachis of the latter. But more than this has been accomplished with wheat. Forms have been developed in which the grains are very readily removed from the glumes. In barley and oats this has not been done to the same extent. We have, it is true, naked varieties of these two cereals, but these varieties have not been extensively cultivated, doubtless on account of their relatively smaller yield, and until a comparatively recent date their cultivation has been confined to the Orient. In wheat, on the contrary, naked grains and a rigid rachis are the general rule, these two characteristics differentiating the cultivated forms from the primitive type and making the former incapable of perpetuating itself without the intervention of man.

CULTIVATED WHEATS WITH A BRITTLE RACHIS.

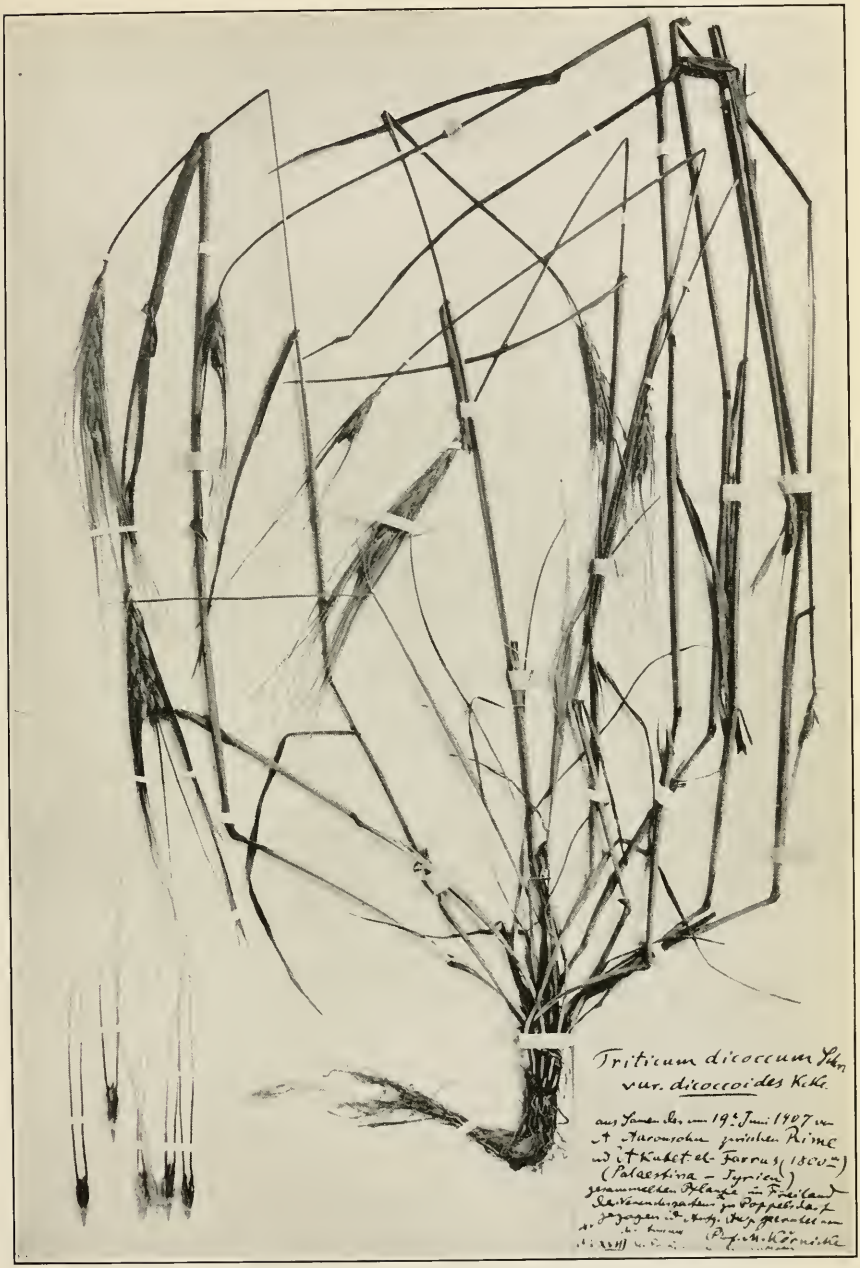
Among the known cultivated wheats there are three that still retain the brittle rachis: Einkorn (*Triticum monococcum*), emmer (*Triticum dicoccum*), and spelt (*Triticum spelta*).

It is known that the cultivation as grain crops of einkorn, emmer, and spelt is steadily decreasing. An attempt has been made in comparatively recent times both in this country and in Russia to cultivate einkorn and emmer as forage plants. It is interesting to note that, except for these attempts, these wheats are cultivated to-day only by the Basques, the primitive Swabians, the Serbes, and that peculiar people the Bactrians of Persia.

The cultivated wheats with a rigid rachis are therefore derived from the wheats with a brittle rachis. But of the three species which have this common character, which one shall we select as the prototype and why make this selection to the exclusion of the others?

EINKORN AND ITS PROTOTYPE DISTINCT FROM OTHER WHEATS.

More than fifty years ago Balansa discovered *Triticum monococcum aegilipoides* in the wild state. This differs from the cultivated *Triticum monococcum* only in minute characters and is without doubt its prototype. Balansa believed that he had found the progenitor of the cultivated wheats, an opinion that Haussknecht also accepted at the time. But experiments in crossing undertaken more than thirty years ago by Vilmorin led him to assert that whereas all the other species of wheats crossed with each other perfectly and gave mongrels, or fertile offspring, he had never succeeded in crossing



TRITICUM DICOCCUM DICOCCOIDES, ENTIRE PLANT.

(Reduced to one-third natural size.)

Triticum monococcum with any other wheat. Later, Beyerinck succeeded in producing the cross, but the products were strict hybrids; that is, they were all sterile. More recently still, Professor von Tschermak, who took up Vilmorin's experiments, met with the same failure. He has succeeded in crossing *Triticum monococcum* with *Triticum ovatum*, which, as we have seen, may in turn be crossed with *Triticum aestivum;* but neither he nor anyone else has succeeded in crossing *Triticum monococcum* with any other wheat.

Let us note, however, that in the case of *Triticum polonicum* there was difficulty in crossing, because of the peculiar form of its glumes, until a particular operative technique had been worked out. In view of this we may question whether the failure with einkorn was not also caused by a faulty technique. We may remark in this connection that, as Doctor Trabut observed,[a] no one has ever succeeded in crossing the two varieties of *Anagallis arvensis*, *caerulea* and *phoenicia*, although the only difference between the two is that the former has blue and the latter pink flowers. But we can not on this account class them as distinct species.

In so far, therefore, as the lack of sexual affinity between two related forms justifies us in recognizing in them two different species, *Triticum monococcum* must be considered as standing alone, and it can not be ranked as the progenitor of the cultivated wheats.

From the historical point of view, also, we may reject einkorn as the progenitor of wheat. Its cultivation can not have gone back to very ancient times, since the cultivated form differs so little from the wild one. The only evidence that we possess of any antiquity is that Schliemann discovered it in his celebrated excavations of ancient Troy, showing that it was cultivated there. But the other cultivated wheats are traced back for thousands of years before this.

Spelt and emmer, then, are the only two forms remaining to be considered, but we have no ancient remains of the cultivation of spelt, nor is there any mention of it in literature until toward the beginning of the Christian era.

EMMER THE ONLY POSSIBLE PROTOTYPE OF TRUE WHEAT.

The species of grain of the cultivation of which we have the oldest records is emmer. It is true that durum wheat has been found in Egypt in some tombs of the first dynasty—that is, four thousand years before the Christian era—but emmer is found both in far greater abundance and in all of the tombs. It is not at the present time cultivated anywhere in Egypt, durum wheat having since historical times taken its place.

[a] Bulletin de la Société Botanique de France, vol. 68, p. 182.

Emmer has been found in the lake dwellings of Wangen and Robenhausen, which date back to the end of the neolithic epoch, a little before the bronze age. This, therefore, is the only species which has been cultivated from the very beginning of civilization, and we are justified in asserting it to be the progenitor of our cultivated wheats. This explains why it was so desirable to find the wild form.

REDISCOVERY OF WILD EMMER IN PALESTINE AND SYRIA.

This was the state of the question when, in the autumn of 1902, I was in Berlin. Professors Ascherson, Schweinfurth, and Warburg at that time called my attention to the importance, from a theoretical point of view, of finding this wild form of emmer. Then only the theoretical phase of the question was under consideration. As I was then living in Palestine, not far from Mount Hermon, I decided to undertake an investigation of this subject. My ambition was simply to rediscover Kotschy's plant, which had definitely taken the name of *Triticum dicoccum dicoccoides*. This name was necessarily given to it in order to conform to the rules of nomenclature; and thus we have, strangely enough, the wild type taking the name of a variety while the cultivated type bears the name of a species. I had the good fortune to rediscover this plant, and I have studied it since 1906.

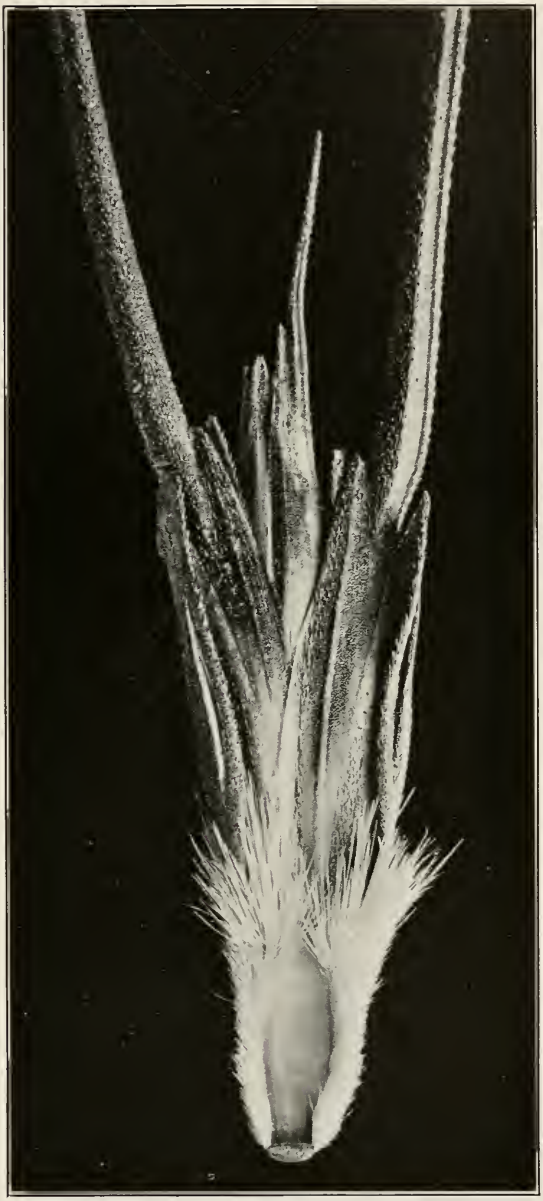
In June, 1904, as I was in upper Galilee preparing a geognostic map of the region, I went as far as the foot of Mount Hermon looking for *Triticum dicoccum dicoccoides*, but failed to discover it. I was not very persistent in my search because I had very little hope of success. I knew that both the late G. Post, the author of "Flora of Syria, Palestine, and Sinai," and Joseph Bornmüller, author of "Beiträge zur Kenntniss der Flora von Syrien und Palästina," had spent a great deal of time botanizing in the neighborhood of Rasheyya, the locality on Mount Hermon from which Kotschy's specimen was supposed to have come. As these skillful botanists did not report any Triticum, I concluded that Kotschy's specimen must in reality have come from some other place—that an error had been made in attributing it to Rasheyya. But when I visited Berlin in the summer of 1905 Messrs. Ascherson and Schweinfurth brought up the question again, and I decided to resume the investigation at the earliest opportunity.

In June, 1906, I took a long trip to upper Galilee, intending to go as far as Mount Hermon and to spend as much time as necessary in looking for *Triticum dicoccum dicoccoides*.

On June 18, I was walking with my friend, the agronomist Mr. M. Bermann, in the vineyard of the Jewish Agricultural Colony at Rosh Pinar, at the foot of Jebel Safed (see Pl. I, fig. 2), and was trying

LOWER FACE OF SINGLE SPIKELET OF TRITICUM DICOCCUM DICOCCOIDES.

(Enlarged about 5 diameters.)



UPPER FACE OF SINGLE SPIKELET OF TRITICUM DICOCCUM DICOCCOIDES.

(Enlarged about 5 diameters.)

to demonstrate to him the Eocene origin of the ground. Suddenly I noticed in a crevice of a rock of nummulitic limestone an isolated plant which at first sight looked like a stool of barley, but which on closer inspection proved to be a wheat, the ripe spikelets of which could be detached from the brittle rachis by the slightest shake. I could hardly believe that it was really the plant for which I was looking. The development of the head and grains was so perfect—so nearly like the forms produced under cultivation at the present day—that I could scarcely believe that this was their wild prototype, though, to be sure, if it had not been so well developed primitive man would not have noticed it, or at least would not have appreciated the importance of its cultivation to such an extent as he did.

I could not at that time remain longer at Rosh Pinar, and so left the next day for the north. On the way from Rosh Pinar to Rasheyya (three days on horseback) I looked for wild wheat, but could not find any. At Rasheyya, too, I spent a great deal of time botanizing in the vineyards in the hope of finding the Triticum there, but also without success. But when I began to extend my search to uncultivated lands, along the edges of roads and in the crevices of rocks, I found a few stools of the wild Triticum. Later I came across it in great abundance, and the most astonishing thing about it was the large number of forms it displayed. The sample specimen from Rosh Pinar, however, was the finest one. This plant had made a very vigorous growth and bore heads the stiff, rugose awns (beards) of which were nearly or quite 6 inches long. (See Pls. II, III, and IV.) At the foot of Mount Hermon the stems were longer but fewer. Instead of being 2 feet high, as at Rosh Pinar, this wild wheat at Rasheyya was more than 40 inches high.

I ascended Mount Hermon and went around to the other side. I intend at some future time to describe this trip, as its botanical and geological results may interest the scientific world; but here I shall speak only of the Triticum. In descending from the summit of Mount Hermon (9,498 feet in altitude) toward Arny, a little village on its eastern slope, I found innumerable forms of this wild Triticum growing in abundance at an altitude of 5,250 feet and less. (See Pl. V, fig. 1.) In some cases the whole ear was black; in others only the glumes or part of the glumes; in still others the awns alone were black. Sometimes the glumes were completely glabrous (see Pl. VI, figs. 1 and 2), sometimes very hirsute (see Pl. VII, fig. 1); in some the form of the glume resembled that of *Triticum durum* (see Pl. VI, fig. 2), in others the development of the secondary nerve was similar to that of *T. monococcum*. (Compare Pl. VIII, figs. 1, 2, and 3.) I had discovered so many forms that no attempt at determination could be made. Among these was even *T. monococcum aegilipoides* (see Pl. VII, fig. 2), a form I had not at all expected to

find. I could therefore only gather specimens, noting their habitat, associations, etc.

As soon as I got home I wrote the good news to my friends in Berlin. A short notice of the results of this trip and an article by Professor Schweinfurth on the importance of this discovery and on the possibilities which it opened up were published.[a]

My trip of 1906 merely established the native habitat of *Triticum dicoccum dicoccoides*. It was still necessary to find out the extent of the distribution, its habit of growth, etc., and I made another trip for this purpose in 1907. The principal results of this trip relating to problems of the cereals in their wild state have been published, with an introduction by Professor Schweinfurth[b] and an appendix by Professor Ascherson, in the proceedings of the Botanical Society of Berlin.

On this trip I was able to show conclusively that *Triticum dicoccum dicoccoides* is indigenous to the regions of Mount Hermon and the northern part of the Trans-Jordan. The idea that it is a plant escaped from cultivation can not be entertained for a moment. In the first place, *Triticum dicoccum* is not cultivated anywhere in Syria and Palestine. I have not been able to discover any hybrid or mongrel between this wild wheat and the cultivated forms. Second—and this is the important point—our *Triticum dicoccum dicoccoides* rarely appears on soils which have been cultivated for any purpose. It grows only upon the slopes of the most arid and rocky hills and in places exposed to the hottest rays of the oriental sun.

DIVERSITIES OF WILD EMMER.

The number of forms of *Triticum dicoccum dicoccoides* which I gathered in 1907 is astounding—"verblüffend," to use Körnicke's own expression. I found specimens in which the glume had a secondary tooth (compare Pl. VIII, figs. 2 and 3), produced by the great development of the secondary nerve, which constitutes a morphological resemblance to *Triticum monococcum*. And, on the other hand, I found forms of *T. monococcum aegilipoides* with the secondary tooth less developed than any that Körnicke had ever seen. We may presume that these were transitional forms.

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[a] See Aaronsohn, A., and Schweinfurth, G., Die Auffindung des wilden Emmers (Triticum dicoccum) in Nordpalästina, in Altneuland Monatsschrift für die wirtschaftliche Erschliessung Palästinas, Berlin, July–August, 1906, nos. 7–8, pp. 213–220; also Prof. Dr. G. Schweinfurth in Vossische Zeitung, September 21, 1906, and in Annales du Service des Antiquités de l'Égypte, 1906.

[b] Schweinfurth, G., Ueber die von A. Aaronsohn ausgeführten Nachforschungen nach dem wilden Emmer (Triticum dicoccoides Kcke.). In Berichte der Deutschen Botanischen Gesellschaft, 1908, vol. 26 a, pt. 4, 1908, pp. 309–324.

FIG. 1.—VIEW OF MEJDEL ESH SCHEMS, ON THE SLOPES OF MOUNT HERMON, WHERE WILD WHEAT WAS FOUND.

FIG. 2.—SCENE IN WADY WALEH, SHOWING THE WRITER'S CARAVAN. WILD WHEAT AND BARLEY GROW ON THE ROCKY HILLS.

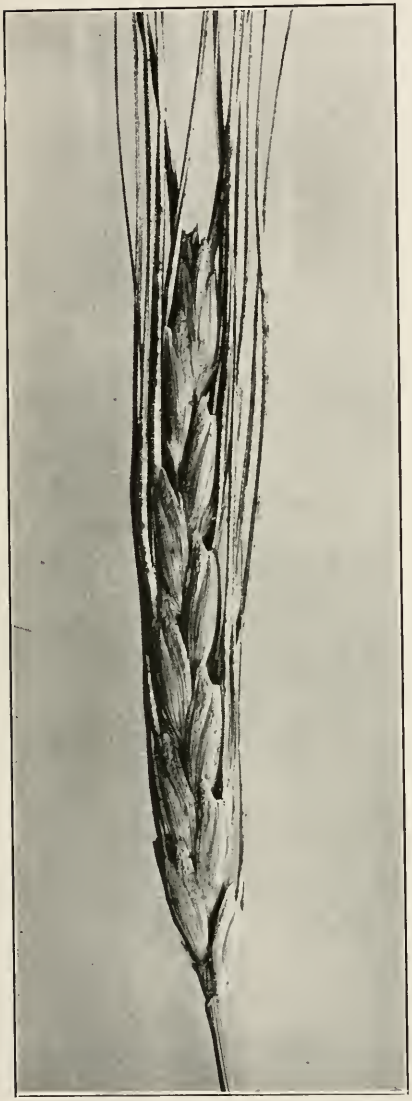

FIG. 1.—SPIKE OF TRITICUM DICOCCUM DICOCCOIDES, SHOWING LONG GLUMES; A TRANSITIONAL FORM TO T. POLONICUM.

(Natural size.)

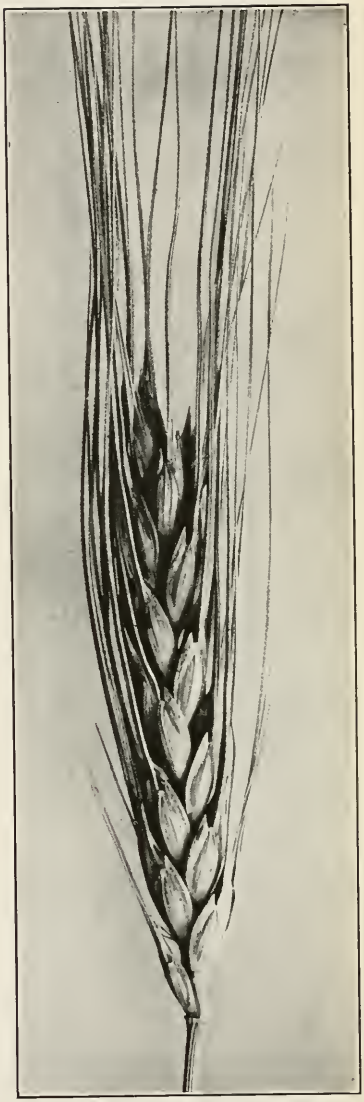

FIG. 2.—SPIKE OF TRITICUM DICOCCUM DICOCCOIDES, SHOWING GLUMES RESEMBLING THOSE OF DURUM WHEAT.

(Natural size.)

I discussed this subject with Körnicke. A year before he had said that certain forms which I had labeled *T. monococcum* were really *T. dicoccum dicoccoides*, and vice versa. But after a minute study of these forms he took pleasure in acknowledging that my determinations were correct, stating this both in his letter to Professor Schweinfurth, dated December 31, 1907, and in his letter to me written a few days before his death.

HABITUAL ASSOCIATION OF WILD EMMER WITH WILD BARLEY.

Another observation of some importance made by the writer is the following:

The wild emmer is always found in company with wild barley. The latter has perhaps a greater area than the former and occasionally is found where wild emmer does not grow, but it is very unusual to find the emmer unmixed with the barley.

Now, it has always been difficult to say whether barley or wheat is the older crop. The oldest writers always speak of these two together, and in excavations in Egypt and elsewhere they are always found associated. Körnicke has asserted that the cultivation of barley is older than that of wheat. But why may we not assume that our prehistoric ancestors began the cultivation of the two cereals simultaneously and that they grew barley and wheat together just as they are found growing when wild? The habits of these two plants are so similar that the Arabs fail to distinguish them, although they are given to more or less close observation of natural phenomena. Several times I have asked the Arabs to gather for me some stools of wild Triticum like the sample which I gave them. They always brought me back *Hordeum spontaneum*. Nor have I been able to find any special word in their language for wild wheat. They always called it "scha'ir barri" or "scha'ir iblisse" (wild barley or devil's barley). But when I asked if it was not wild wheat. they admitted that it was "kamh barri" (wild wheat), being eager, as the Arab always is, to agree with the opinion of a guest.

DISCOVERY OF RYE, BOTH WILD, AND CULTIVATED, IN SYRIA.

On my 1907 trip I was able to demonstrate that *Triticum dicoccum dicoccoides* and *Triticum monococcum aegilipoides* are indigenous to the vicinity of Mount Hermon; to study their distribution, their preferences as to location, and their habits of growth; and to gather a number of intermediate forms, and to study their association with each other and with *Hordeum spontaneum*. But, in addition to this, I made another discovery which I should like to mention.

I found some stools of cultivated rye (*Secale cereale*) at Damascus in a field of wheat. Now, two days later at Zebedani, on the Anti-

Lebanon, I gathered a stool of *Secale montanum*. It is an interesting fact, too, that the wheat in which the cultivated rye was found was *Triticum durum melanopus* (*T. complanatum*), having a starchy and not a glassy grain.

Now, it has been asserted as a fact that in ancient times as well as in our own day rye has been unknown to the Orient. Philologists were ignorant of the special name for this cereal in the Orient, and they therefore concluded that rye must have originated in Europe. It was on this theory that Hoops, Much, and others based their conviction that the cultivation of the cereals originated in Europe. No one who knows how strongly Damascus has resisted European influence, even up to the present time, can for a moment believe that the rye which I found in the wheat field had been imported. It is to be noted, too, that the region to the east and the north of Damascus is almost unexplored, and it may therefore be that without our knowledge rye is more or less cultivated there. I have not yet found out the special name the Arabs use to designate this cereal.

WIDE RANGE OF WILD EMMER.

In 1908 I was commissioned by the Turkish Government to make a scientific exploration around the Dead Sea, and was thus enabled to extend my study of *Triticum dicoccum dicoccoides*.

While descending Engedi, on the western shore of the Dead Sea, in March, 1908, I noticed a plant of *Hordeum spontaneum* with unripe heads, but gave it no particular attention. On March 26, having gone around the Dead Sea to the south and having pushed tolerably far into Arabia, our caravan reascended from El-Mazra-a on the southeast shore of the Dead Sea, 1,300 feet below sea level, toward the plateau of Moab, which is in some places more than 3,300 feet above sea level. At 350 to 500 feet above the Dead Sea, where the salty marls began to give place to calcareous strata, we saw *Hordeum spontaneum* more and more frequently. The abundance of this and the conditions of soil and vegetation made me think at once of the wild emmer. But, though I looked carefully, I could not find it either that day or on the three following days, although wild barley was as plentiful as before. I attributed this to the season, for the barley had barely headed and the wild emmer, if there, would have been concealed. On March 28 we camped in the Wady Waleh (see Pl. V, fig. 2), with which we were familiar from a preceding exploration around the Dead Sea and where, on February 29, 1904, Professor Blanckenhorn and I had discovered flint implements from a paleolithic, or perhaps even an eolithic, epoch at the foot of the rude stone columns called "menhirs," some of which were overturned and some still standing (see fig. 12).

FIG. 1.—SPIKE OF TRITICUM DICOCCUM DICOCCOIDES, SHOWING LONG GLUMES; VERY HIRSUTE.

(Natural size.)

FIG. 2.—SPIKE OF TRITICUM MONOCOCCUM.

(Natural size.)

FIG. 1.—SPIKELET OF TRITICUM MONOCOCCUM, SHOWING THE CHARACTERISTIC SECONDARY TOOTH OF THE GLUME. FIG. 2.—SPIKELET OF TRITICUM DICOCCUM DICOCCOIDES, SHOWING THE SECONDARY TOOTH, AS IN T. MONOCOCCUM. FIG. 3.—SPIKELET OF TRITICUM DICOCCUM DICOCCOIDES, SHOWING THE ABSENCE OF THE SECONDARY TOOTH OF THE GLUME.

(All enlarged 4 diameters.)

At this latter visit the hills which bordered the Wady Waleh were so abundantly covered with wild barley that they and the valleys looked like fields of cereals sown irregularly and infested with weeds. I tried to picture in my mind the life of our prehistoric ancestors who lived on the banks of this delightful wadi (canyon). I believe, as does Eduard Hahn, that our ancestors were not exclusively hunters and shepherds, as they are generally supposed to have been. They were without doubt chiefly vegetarians, and in this region, where the growing season is very short, they must have learned at a very early date to gather and preserve grain. Their life here must have been a comparatively enviable one. The negroes of Africa are compelled to make bread from a species of Pennisetum and from certain

FIG. 12.—Monolith in Wady Waleh. At its foot paleolithic or eolithic flint implements were found. Wild wheat and barley were found on the hills in the background.

Poas, which are very hard to harvest; the peoples of the Sahara with great labor secure a coarse bread from the seeds of *Panicum turgidum* and of *Aristida pungens*, which latter is even in our day an article of commerce; the Touaregs live on the seeds of different Diplotaxis, *Eruca sativa*, *Senebiera lepidoides*, and other crucifiers; the Tibbus, of Siwah, live on bread made from the seeds of colocynth.[a] When we think of what these and other peoples of our own day have to use for food, we must acknowledge that the prehistoric inhabitants of the valleys and plateaus of the Trans-Jordan were to be envied when they had *Hordeum spontaneum* and, as we anticipated, *Triticum dicoccum dicoccoides* also in abundance. (See Pl. IX, figs. 1 and 2.)

[a] See Duveyrier, Les Touaregs du Nord, p. 204; P. Soleillet, L'Afrique Occidentals, p. 177; and Nachtigal, Sahara und Sudan, vol. 1, p. 249.

Everything here seemed to be favorable to the growth of the wild emmer. So, when I returned to Jerusalem in April, I communicated to Professor Schweinfurth my hypothesis that *Triticum dicoccum dicoccoides* grew in the country of Moab, as he continued to take an interest in my travels and has called my attention to a number of problems which otherwise would have escaped me. I resolved to return to the country of Moab at a more favorable time, in May, for example. My joy was unbounded when, on returning to the country of Moab and Gilead two weeks later, April 17, 1908, I found *Triticum dicoccum dicoccoides* while going from Tell Nimrin, in the valley of the Jordan, to Ain Hummar, on the plateau of Es-Salt. A little later it was found as plentifully as it had been in the neighborhood of Mount Hermon.

SOILS AND LOCATIONS PREFERRED BY WILD EMMER.

I may summarize my observations on *Triticum dicoccum dicoccoides* as follows: It is always found in the same sort of habitat—in the crevices of rocks, in places where the rocks are covered with only a thin layer of soil, in the most arid situations and those most exposed to the sun (see Pl. I, fig. 2, and Pl. V, figs. 1 and 2), and always associated with *Hordeum spontaneum*. In locations where the vegetation is abundant and the soil fertile and where the layer of "terra rossa" has increased in depth by the disintegration of the rock, *Triticum dicoccum dicoccoides* is not found, except in the shelter of clumps of bushes and small trees, such as *Poterium spinosum*, *Cistus villosus*, *Zizyphus spina-christi*, *Echinops viscosus*, *Centaurea* sp., etc. This was observed to be the case at Mount Hermon (see Pl. V, fig. 1), at Rosh Pinar (see Pl. I, fig. 2), and in the country of Gilead (see Pl. V, fig. 2).

As to the geological age of the rocks, I have found *Triticum dicoccum dicoccoides* on the Jurassic limestones and dolomites, on the so-called sandstones of Nubia, on the more or less dolomitic limestones of the Cenomanian and Turonian, and on the lower Eocene limestones, as well as on the basalts and basaltites. The only formations on which it does not thrive seem to be the Senonian rocks (made up chiefly of chalky and soft limestones or of flints) and the Nari, a conglomerate generally formed of elements of Senonian origin and similar to the "caliche" of the southwestern United States. This was observed at Gilead, as well as in the neighborhood of Rosh Pinar. In this latter locality I made sure that *Triticum dicoccum dicoccoides* was not to be found on the Senonian formations, which are there very extensive and varied, being represented by chalky marls, bituminous limestones, and limestones of *Schloenbachia olivetti*.

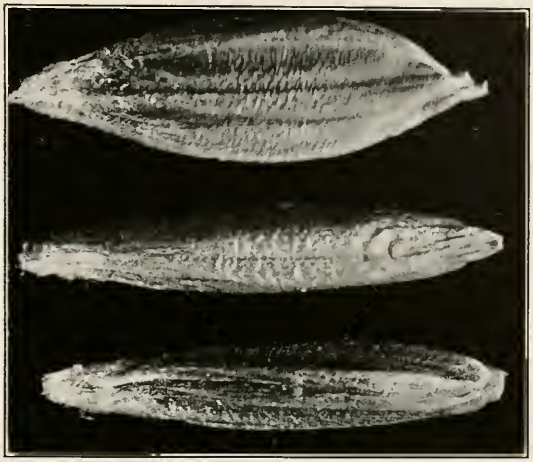

FIG. 1.—GRAINS OF TRITICUM MONOCOCCUM; SIDE, DORSAL, AND VENTRAL VIEWS.

(Enlarged 8 diameters.)

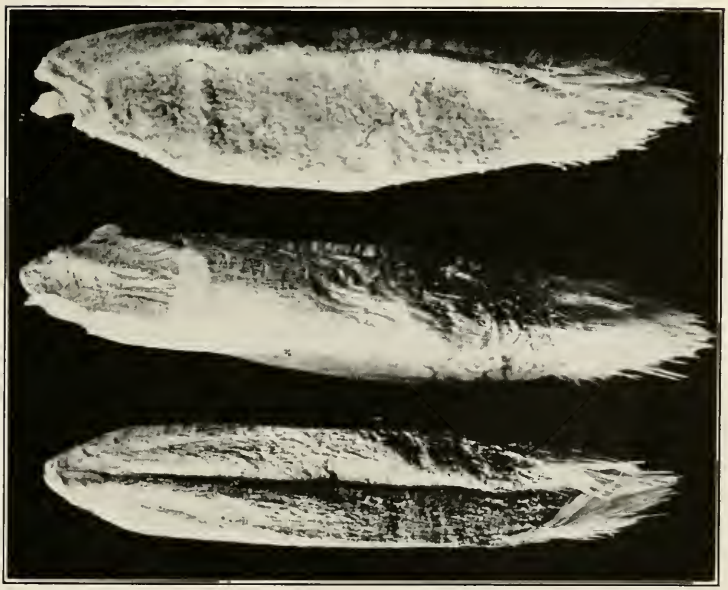

FIG. 2.—GRAINS OF TRITICUM DICOCCUM DICOCCOIDES; SIDE, DORSAL, AND VENTRAL VIEWS. NOTICE THE HAIRY APEX.

(Enlarged 8 diameters.)

We have seen that the wild emmer prefers rocky soils and has not been found up to the present time on the broad plains and vast steppes. Thus, I could not find it at the Ghor (the depression of the valley of the Jordan) either in 1907, when I searched for it in the neighborhood of the Lake of Tiberias, or in 1908 at the mouth of the Jabbok. It disappeared also on the road from Rasheyya to Katana when we reached the Senonian formations and the steppe toward the east. It does not seem even to extend to the edges of the rocky ground, but leaves a sort of protecting belt of rocky land between it and the alluvial, diluvial, or oolithic soils which border it.

Further search ought to be made to find out how far *Triticum dicoccum dicoccoides* extends toward the southeast of the country of Moab and toward Arabia, as well as how far north along the Lebanon and the Anti-Lebanon. Moreover, we should look further in the Cis-Jordan region, where it probably extends farther than the territory lying between Rosh Pinar and the northern part of Lake Tiberias.

WHERE DID THE CULTIVATION OF CEREALS ORIGINATE?

I believe that a careful consideration of the foregoing facts will throw some light on the question of the origin of the cultivation of cereals. I shall consider only three of the numerous hypotheses formulated in regard to this problem: First, there is the ingenious theory of the Count of Solms-Laubach, set forth in his work "Weizen und Tulpe," etc., previously cited.

He admits the polyphyletic origin of *Triticum aestivum*, but, having definite proof that wheat was cultivated in Egypt at least four thousand years before the Christian era and at least three thousand years before the same era in China and assuming that the Egyptian and Chinese civilizations were entirely independent and without influence upon one another, he reaches the conclusion that the cultivation of *Triticum monococcum* and of the prototype of *Triticum aestivum* must have begun in an age so remote that the division of land and sea, the climatic conditions, and the resultant flora were very different from those of the present day. It must, then, have taken place in central Asia, in the neighborhood of the basin of the Tarim, and at a time when the Desert of Gobi was still covered by the sea of Han-hai. Later, *Triticum monococcum* must have emigrated westward, while the prototypes of *Triticum aestivum* disappeared and only their cultivated descendants reached the west. But according to recent research it is not so certain that the Egyptian civilizations were entirely independent, and we hesitate to accept a theory which is doubtful in its conclusions, even though based on irrefutable geological premises.

Körnicke, as well as Schweinfurth and Ascherson, has always thought that the cultivation of wheat originated in western Asia in the region of the Euphrates. A. de Candolle also reached the same conclusion nearly thirty years ago as a result of his study upon the origin of cultivated plants. We take pleasure in quoting him: "The Euphrates Valley lying nearly in the middle of the belt of cultivation which formerly extended from China to the Canaries, it is extremely probable that this valley was the principal habitation of the species in very early prehistoric times. The area may have extended toward Syria, as the climate is very similar, but to the east and west of western Asia wheat has probably never existed but as a cultivated plant, anterior, it is true, to all known civilization."

The most recent theory—that claiming that the cultivation of cereals originated in Europe—has been discussed elsewhere,[a] and it hardly seems worth while to bring it up again. No naturalist will agree with Much, Hoops, and the other supporters of this hypothesis.

SUMMARY OF STUDIES OF THE WILD CEREALS.

I may say as a summary of the result of my investigations—

(1) I have fully confirmed the opinion of Körnicke, who was the first to assert that the specimen collected by Kotschy was a wild emmer, named by him *Triticum vulgare* [*dicoccum*] *dicoccoides*. This Triticum is a native of southern Syria and is the prototype of our cultivated wheats, or at least one of the oldest forms derived from such a prototype.

(2) I have shown that *Triticum monococcum aegilipoides*, as well as *Secale montanum*, is indigenous to the region of Mount Hermon and that rye (*Secale cereale*) occurs in the Orient, where it was thought to be entirely unknown.

(3) I have found forms morphologically intermediate between *Triticum dicoccum dicoccoides* and *T. monococcum aegilipoides*. Experiments in crossing, which are to be made later, will show whether these forms are only morphologically intermediate or whether they have closer sexual affinities than those which exist between the cultivated forms of *Triticum dicoccum* and *T. monococcum*.

(4) I have collected certain forms of *Triticum dicoccum dicoccoides* in which the development of the glumes and the whole appearance of the head recall *Triticum polonicum*.

(5) We have seen that *Hordeum spontaneum* is a satellite, so to speak, of *Triticum dicoccum dicoccoides*, and that the cultivation of the two species may have been begun at the same time.

[a] Aaronsohn, A. Contribution à l'Histoire des Céréales. Bulletin de la Société Botanique de France. March–April, 1909.

(6) I believe that the existence of all of these prototypes—that is to say, of oats, wheat, barley, and rye—in a single region, Syria and Palestine, tends to show that the cultivation of cereals must have originated there, or at least in closely adjoining localities.

ECONOMIC POSSIBILITIES OF WILD EMMER.

Hitherto we have devoted our attention to the theoretical and purely scientific phase of this question, but I have thought from the first that it may have a practical and economic interest. The fact that *Triticum dicoccum dicoccoides* endures the most extreme climatic conditions seems to me to be very important when we consider the future economic possibilities of the plant. Its distribution extends vertically for more than 6,500 feet. I have found it from 325 to 500 feet below the Mediterranean in the vicinity of the Jabbok (eastern tributary of the Jordan) and up to 6,000 to 6,300 feet above sea level at Mount Hermon, in the zone of alpine plants.

By the selection and crossing of this wild cereal, which prefers poor, rocky, shallow, dry soil and thrives without any cultivation, we should be able to produce new races which will be very persistent and very hardy. In this way we can extend the cultivation of wheat to regions where it is at present impossible on account of the low quality of the soil and the severity of the climate.

The writer has had the pleasure of seeing that many eminent scientists and practical men share this opinion. Körnicke's son and Mr. M. A. Carleton, the Cerealist of the Bureau of Plant Industry, are working on this problem. In the Vossische Zeitung for September 3, 1908, Professor Schweinfurth gives an account of the experiments carried on by the late Professor Körnicke, which will be continued by his son and successor in the chair of botany in the Agronomic Institute of Bonn-Poppelsdorff.

Of the thirty-six plats sown the first year of Körnicke's experiments more than thirty produced splendidly developed heads. Professor Schweinfurth shares my belief that this cereal shows very exceptional hardiness and adaptability, and he is certain that by selection and crossing we shall obtain some races especially adapted to arid regions and other races valuable for cold and elevated localities. Out of thirty-six plats sown last year, thirty-five came to fruition, and some of them produced heavier and more beautiful seeds than any of our cultivated wheats.

The countries adjoining the regions where *Triticum dicoccum dicoccoides* has been found should be carefully explored. We should determine its exact area of distribution and thoroughly study its numerous varieties and forms, their life history, pollination, etc. This would place us in a position to utilize these wild varieties to

the best advantage in the creation of new cultural races. It is impossible to foresee the importance of the results that may be thus obtained. Those who know what is being done at present in the way of creating interesting races by selection and with our present methods of hybridization will agree with me in saying that the cultivation of wheat may be revolutionized by the utilization of these wild forms.

It seems to me that we are justified in hoping to produce races better adapted to the semiarid regions of Algeria, Tunis, Syria, Egypt, Turkestan, and America. If we secure races that will enable us to increase the yield by as much as 1 bushel per acre on these vast areas, the world's total production of wheat will be very materially augmented.

The study of the wild types of our cereals should not serve merely botanical and historical ends. It has a practical, an economic—I may even say a social—importance. Its ultimate aim is to produce a little more bread at a little less expense where production is difficult and costly, and to render this production possible where up to the present time it has been impossible.

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B. T. GALLOWAY, *Chief of Bureau.*

THE CURLY-TOP OF BEETS.

BY

HARRY B. SHAW,

ASSISTANT PATHOLOGIST IN COTTON AND TRUCK DISEASES AND SUGAR-PLANT INVESTIGATIONS, IN COOPERATION WITH THE BUREAU OF ENTOMOLOGY.

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[Continued on page 3 of cover.]

U. S. DEPARTMENT OF AGRICULTURE.
BUREAU OF PLANT INDUSTRY—BULLETIN NO. 181.
B. T. GALLOWAY, *Chief of Bureau.*

THE CURLY-TOP OF BEETS.

BY

HARRY B. SHAW,

ASSISTANT PATHOLOGIST IN COTTON AND TRUCK DISEASES AND SUGAR-PLANT INVESTIGATIONS, IN COOPERATION WITH THE BUREAU OF ENTOMOLOGY.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., February 25, 1910.

Sir: I have the honor to transmit herewith and to recommend for publication as Bulletin No. 181 of the Bureau series a manuscript entitled "The Curly-Top of Beets," by Harry B. Shaw, Assistant Pathologist in Cotton and Truck Diseases and Sugar-Plant Investigations of this Bureau, in cooperation with the Bureau of Entomology.

The sporadic outbreaks of this disease have caused much loss to sugar-beet growers in our Western States during the past ten years. Curly-top has been under investigation by this Bureau since 1902, and Bulletin No. 122 of this Bureau, by Dr. C. O. Townsend, was published in 1908 to show the lack of proof that bacteria, fungi, or unfavorable environmental conditions were the cause of curly-top. Since that date Mr. Shaw has proved that the disease results from the punctures of an insect, a theory previously advanced by Dr. E. D. Ball, then special agent of the Bureau of Entomology. This group of plant diseases, another example of which is stigmonose of carnations, described by Mr. A. F. Woods in Bulletin No. 19 of the Division of Vegetable Physiology and Pathology, is of special interest to the plant pathologist on account of the physiological problems involved, but the practical control of these troubles must be based largely upon studies by the entomologist.

To make this discussion of curly-top more complete and of greater practical value Mr. Shaw has included a description of the beet leafhopper and its life history, largely drawn from the work of Dr. E. D. Ball, whose assistance, and that of Dr. F. H. Chittenden, of the Bureau of Entomology, is gratefully acknowledged.

Further knowledge of the most effective means of control is hoped to result from studies planned in cooperation with the Bureau of Entomology.

Respectfully,

G. H. Powell,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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THE CURLY-TOP OF BEETS.

INTRODUCTION.

Through various publications the serious nature and general character of the curly-top of beets are fairly well known, either under that name[a] or more locally as "blight," "western blight," or "whiskered beets." These names are descriptive of one or another of the symptoms manifested by the stricken plants. Apparently no kind of beet is immune.

Recent experiments and observations have demonstrated not only the primary cause of this disease, but that it is an even greater menace to the production of beet seed than to the culture of beets for sugar.

SYMPTOMS OF CURLY-TOP.

EXTERNAL SYMPTOMS.

The external symptoms of curly-top are numerous and may be found in all parts of affected plants. Commonly the earliest to appear is an inward curling of the inner leaves from the entire margin toward the midrib. Almost simultaneously a distortion of the veins of the affected leaves may be noted; these become crinkled and knotted on the dorsal surface of the leaf (Pl. I, fig. 1, and Pl. II, fig. 1). As the disease progresses more leaves, and finally the whole plant, become involved; nipple-like protuberances develop on the veins, sometimes to the length of about three-sixteenths of an inch, and the whole leaf becomes tightly curled from either side. The petioles remain much shorter than in the normal plant (fig. 1) and become bowed, with the concavity inward; the crown is generally quite perceptibly wider than in the healthy beet, owing largely to an abnormal growth of small and imperfectly formed leaves outside of and around the original set of leaves; and the leaves and petioles bunch closely

[a] "Blight" is used in so many other connections that it is deemed better to avoid its use in this paper; neither is "curly-leaf" considered quite as inclusive as "curly-top," since the latter term includes crown, petioles, leaves, and seed stems. However, it is acknowledged that "curly-top" is not an ideal name, because it fails to include the disturbances found in the root.

together instead of opening out and spreading (Pl. II, fig. 2, and Pl. III, fig. 1).

The foliage is generally of a dark, dull-green color and quite brittle, though thick and leathery in appearance. In severe cases, especially among young plants, the outer leaves soon become yellow, die, and turn brown; the inner whorls follow, until the entire plant is killed.

The roots throw out dense masses of rootlets from the two spiral grooves; hence the names "hairy-root" and "whiskered beets." (See Pl. II, figs. 1 and 2.) The root itself looks tough and fibrous and in many cases becomes sprangling. When pulled up, masses of soil cling to the hair-like rootlets and are with difficulty shaken off. The growth of every portion of the plant is checked, if not entirely arrested.

FIG. 1.—Healthy sugar beets, Vilmorin type. (For comparison with beets affected by curly-top.)

In many cases the leaf-curl assumes an alternative form. Instead of an inward curl, the leaf as a whole becomes strongly retracted and each portion between the larger veins is puffed out. This results in a blistered or "savoyed" effect. In this latter type the vein symptoms are not usually so pronounced. Sometimes the two types are combined; the leaf as a whole is then retracted, but the margin curls inward (figs. 2 and 3). Frequently wine-colored stains develop in the form of small circular spots over the surface of leaves of mangel-wurzels and garden beets, but no local discoloration has been noted on sugar beets except a faint mottling of young leaves which can only be seen by transmitted light.

INTERNAL SYMPTOMS.

Certain distortions of the cells of the tissues of leaf and stem have been observed in beets affected with curly-top; the fibro-vascular bundles may become darkened throughout the entire length of the root (Pl. III, fig. 2). No decay or softening of the tissues has been noted as a direct consequence of the disease; on the contrary, the root becomes tougher and more fibrous, thus rendering the slicing of the beets more difficult, with frequent clogging of the cutters. In many

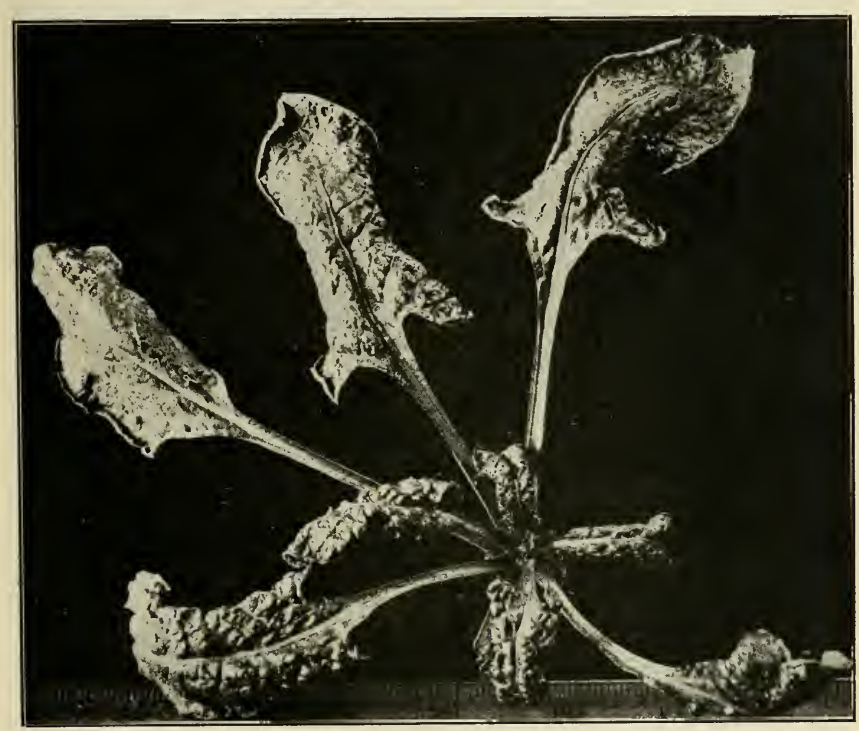

FIG. 2.—Curly-top sugar beet, face of leaves, showing retracted type of curl. Disease produced under test conditions by gradually increasing number of beet leafhoppers until curl developed. Plant at start three and a half months old.

roots a blackened area, or even a cavity with black walls, may be found in the interior of the crown (27[a]) (Pl. III, fig. 2); this latter symptom may, however, be found under other conditions (3, 9, 11, 13, 16, 24, 29) and is not considered characteristic of curly-top alone. Very young beets may be so severely attacked that they are killed before the symptoms have time to develop.

[a] The serial numbers in parentheses used in this paper refer to the bibliography on pp. 37–40.

SYMPTOMS IN SEED BEETS.

When beets are grown a second season for the production of seed the symptoms of the plants affected with curly-top are similar to those already described, but a much larger proportion of the retracted type prevails. In addition, many seed beets[a] are quite unable to develop seed stems; instead, the leaves gradually wither and the whole plant dies. In other cases feeble stems are produced which

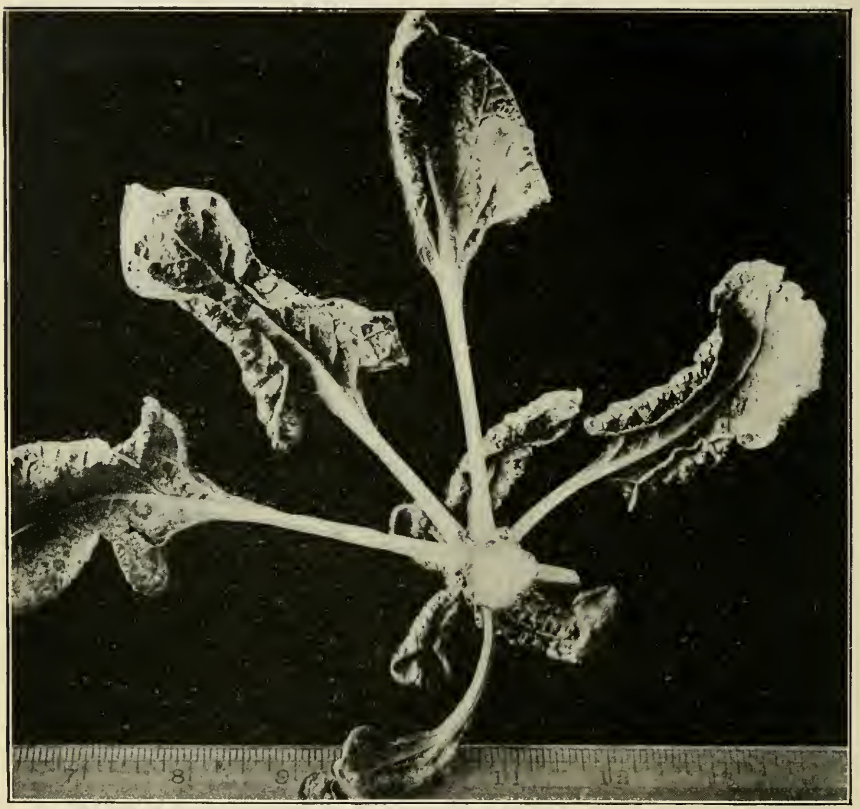

FIG. 3.—Curly-top sugar beet, dorsal surface of leaves; the same plant shown in figure 2.

may or may not reach the flowering stage and then dry up and die; still others possess enough vitality, though badly dwarfed and stunted, to bear and mature seed (Pl. VI, fig. 1).

Quite frequently the roots of seed beets affected with curly-top are found to have rotted areas of varying extent, sometimes involving

[a] While the term "mother beet" is probably the more familiar one, "seed beet" is considered better, inasmuch as beet flowers contain both male and female organs. The term "mother beet" implies that the flowers of the seed-bearing plant contain only the female organs.

the greater part of the root (Pl. VIII, fig. 1). This is not to be attributed to curly-top, but is probably brought about by the entrance of various organisms, such as *Phoma betae*, Rhizoctonia, etc. On the other hand, the root may remain sound and crisp, though the top may exhibit every symptom of a severe case of curley-top (Pl. VIII, fig. 2).

ONLY ONE SYMPTOM REALLY CHARACTERISTIC.

It is to be remarked that most of the symptoms of curly-top, taken individually, may appear under other pathological or physiological conditions; so far as observed, the one real exception is the vein symptoms. However, the totality of the symptoms described in this connection has not been observed apart from curly-top.

CAUSE OF THE DISEASE.

THEORIES.

Until quite recently the cause of curly-top was unknown. Numerous theories have been advanced to account for it. Among the more plausible are the following: Bacteria, fungi attacking the leaves, fungi attacking the roots, insects, abnormal moisture supply, abnormal soil conditions, poor seed, and a combination of unfavorable conditions (26, 27).

After wide field observations Dr. E. D. Ball, then special agent of the Bureau of Entomology, stated (4, 5, 6) that in his opinion the disease is caused by the beet leafhopper[a] (*Eutettix tenella* Baker, Pl. I, fig. 1). Prof. E. G. Titus, formerly collaborator of the Bureau of Entomology, while engaged in entomological experiments observed the appearance of curly-top on beets in breeding cages in which some beet leafhoppers were found (6; also footnote, p. 23).

PRELIMINARY EXPERIMENTS.

The writer first turned his attention to the curly-top of beets late in the summer of 1907. Early in June of that year he had noted in the experimental field at Garland, Utah, a few cases of the disease among sugar beets. The earliest of these were among pedigree strains and among garden beets, both of which germinated and grew with much less vigor than the standard varieties of sugar beets. As the season advanced more cases appeared sporadically throughout the field.

[a] In this paper the beet leafhopper (*Eutettix tenella* Baker) will be referred to simply as the leafhopper.

Among the standard varieties there was apparently little difference in susceptibility. Several species of leafhopper were noted as being generally, though not abundantly, distributed over the field. A small lot of seed was sown in July; quite late in the season some of the seedlings were inclosed in a cheesecloth-covered cage to exclude leafhoppers and other insects.

No curly-top developed among the caged plants; some cases appeared in the open row. This experiment was of little value, because all of the plants had been exposed to insects for some time before any of the plants were isolated. Plans were then made to observe the beets with special reference to this disease from the outset of the following season.

With the beginning of the season of 1908 various experiments were started looking to the solution of this problem. These covered, in a preliminary way, almost all the ground suggested by the theories heretofore mentioned, with negative results so far as curly-top is concerned. The ground being thus cleared, the experiments were focused on the study of the effects of the work of certain sucking insects, notably thrips, red spiders, aphides, and leafhoppers, all of which were numerous in our field at Garland.

It was observed that each of these insects produced characteristic effects on beet leaves. At the outset it was deemed desirable to ascertain the specific effects of the attacks of each kind of insect upon beets. This was desirable not only to determine conclusively whether any of these might produce the curly-top symptoms, but, in case they did not, to know just what the effects of each might be. Since all of these insects abound on beets, it was necessary to be able to discriminate the work of each one from that of the others. Then, in case it was found impracticable entirely to exclude the tiny insects from beets isolated with leafhoppers, it might be easy to distinguish effects that could not have been produced by thrips, red spiders, or aphides. In practice it was possible to exclude all except a very few thrips, which entered the cages through the soil.

ISOLATION CAGES.

The construction of some of these cages will be understood on referring to figures 4 and 5. A foundation frame of $\frac{7}{8}$ by 6 inch lumber was used. This was sunk in the soil about 2 inches to prevent the entrance or egress of insects beneath the cage. Upon this foundation a frame of laths, stout wire, or $\frac{1}{4}$-inch soft iron rods bent into hoops was made (fig. 5). Over the frame was stretched

loosely a covering of chiffon or silk veiling; then over that one of Brussels netting (figs. 4 and 5). The chiffon is impenetrable to the insects, but will not withstand the weather; the Brussels net

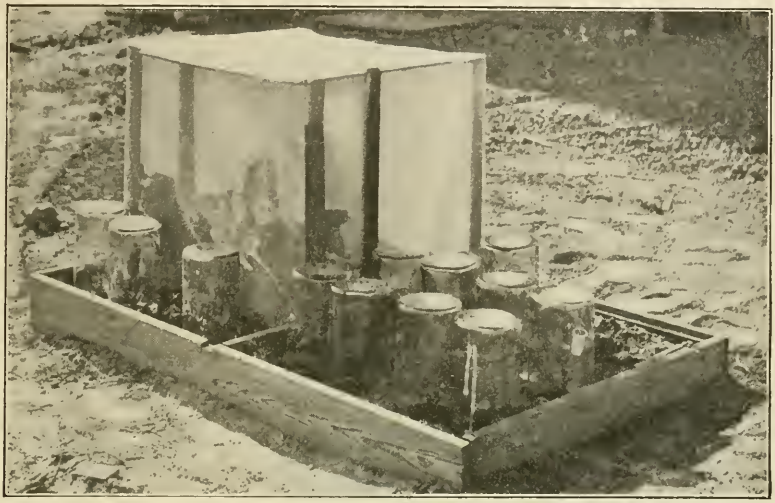

FIG. 4.—Isolation cage and Mason jars for isolating sugar-beet plants.

is strong, but will exclude nothing smaller than adult leafhoppers; therefore both materials were used together. These covers were drawn well down the sides of the foundation frames and secured

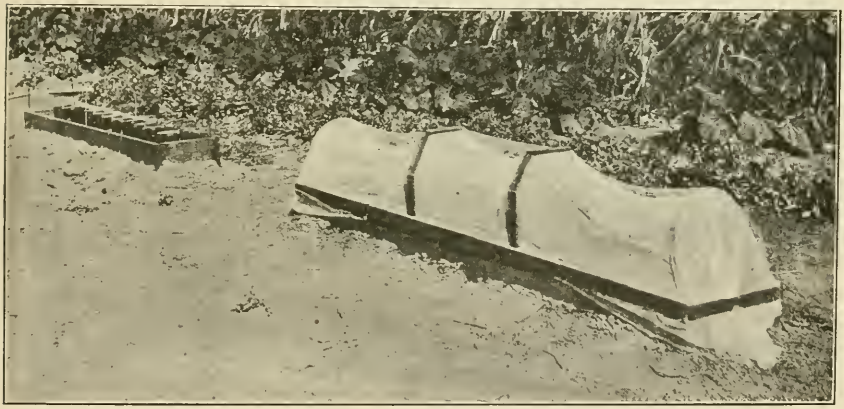

FIG. 5.—Another type of isolation cage.

there by tacking laths over their free margins to the sides of the foundation frame. Special care was taken to make the corners tight. To place insects in the cage a lath was temporarily removed

from one side and the edge of the cover raised. The hoops of iron rod are especially useful for cages, covers, etc., and may readily be made by bending lengths of the rod over the edge of a board that has been cut to the proper size and shape, as shown in figure 6. It will be noted that the sides of this board are convergent. This is done to take up the resilience of the iron rod; otherwise the hoops would straddle too much.

In cages 1 and 2 a standard strain of beet seed was sown on July 18, and more on August 4. This germinated and grew under isolation conditions. Red spiders and aphides were excluded, but a few thrips gained entrance through the soil. Cage 1 was carefully partitioned into three insect-proof chambers. Colonies of thrips were introduced into chamber *a*; into *b* six adult beet leafhoppers were placed, and into *c* red spiders from the beets in the open field. Aphides were placed on beets in cage 3. Cage 2 was reserved as a "control." This was done on August 25; from that time the record of cage 1 is as follows:

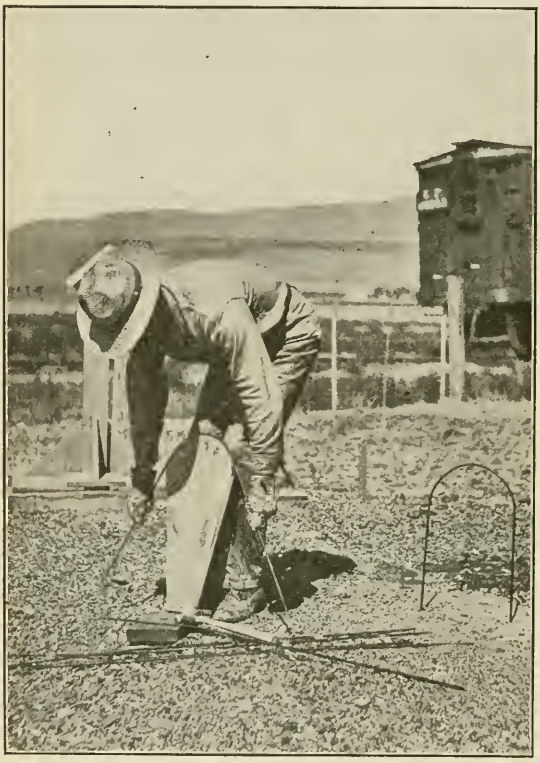

FIG. 6.—A simple method of preparing iron hoops for cages, etc.

August 28. Four more placed in *b*.

September 7. (*a*) Plants made good growth; leaves dark green, many of inner ones badly distorted, some being "savoyed" and some cup shaped by thrips' attacks. (*b*) Scarcely any growth made; leaves dull, leathery, and somewhat blotched or faintly mottled when seen by transmitted light; some leaves strongly concave; no vein symptoms. (*c*) Conditions similar to *a*.

September 8. Placed a few more hoppers in *b*.

September 12. (*b*) Four of the earliest sprouting seedlings show some curl on margin of inner leaves.

September 17. (*b*) Several more hoppers introduced. One leaf completely curled.

September 21. (*b*) Three plants show distinct curly-top symptoms on one or more leaves.

September 28. (*b*) Six plants affected with curly-top.

October 15. (*b*) All plants plainly affected.

None of the control plants became affected with curly-top, nor did any of those in compartments *a* and *c*. Most of the seedlings in this experiment were only about ten days above ground and possessed but two pairs of true leaves when the first hoppers were introduced. The first unmistakable signs of curly-top were noted within thirteen days after the introduction of leafhoppers.

In another frame beet seed had been sown on June 10; this frame was immediately covered with netting to exclude hoppers. Some preliminary experiments, already mentioned, were tried in this frame, but, as stated, with negative results so far as curly-top is concerned. The plants were simply checked in growth. On August 12 this frame was divided in the same way as cage 1. Compartment *a* was used for controls and *b* for the confinement of leafhoppers, and the plants in *c* were individually covered with inverted 2-quart Mason jars as follows: Nos. 1, 2, 3, and 10 with thrips; Nos. 6, 7, and 8 as controls; No. 4 with red spiders and thrips; Nos. 11 and 12 with red spiders; No. 5 with four leafhoppers; and No. 9 with two leafhoppers. At the beginning of this experiment these plants were two months old. The outer leaves were stripped off so that those remaining should not be too crowded under the jars. All the leaves left on the plants were immature, and in them active cell division was in operation. The record for this cage is as follows:

September 1. No. 5, inner leaves curing and vein symptoms showing (Pl. IX, fig. 1); all controls unaffected, except from confinement under glass.

September 4. No. 9, inner leaves curling and vein symptoms appearing; controls still normal.

In eighteen days curly-top symptoms appeared on the growing leaves of plants two months old at the start, with only four and two adult leafhoppers, respectively. Several days after the insects were imprisoned some of them became inoperative because they stuck to the wet walls of the jars. The plants were constantly bathed in moisture during this experiment.

On August 26 a cage was placed over a 2½-month beet. Four leafhoppers were placed in this cage. On August 30, four more hoppers were placed in this cage. On September 6, the inner leaves were curling and vein symptoms appeared. (See Pl. IX, fig. 1.)

Early in September some living beet leafhoppers were sent in mailing tubes to Dr. C. O. Townsend, at Washington, D. C. These were placed on beets in isolation cages in the greenhouse, as follows: September 9, two hoppers; September 16, four more hoppers intro-

duced; October 5, four of the eleven plants now have decidedly curled leaves; October 8, seven plants now affected; October 14, nine plants now affected; October 23, ten affected. The beets grown in the open greenhouse beds remained healthy. The beets were quite young; the hoppers were adults.

In still another experiment in the Garland field some adult leafhoppers were placed in a cage with beets not less than three months old, the outer leaves being first stripped off. In this case the disease was longer in manifesting itself, but when it appeared it took the retracted type (figs. 2 and 3).

NYMPH OF BEET LEAFHOPPER MORE HARMFUL THAN THE ADULT.

During the season of 1909 the writer sent other lots of beet leafhoppers to the Office of Sugar-Plant Investigations, at Washington, D. C., and duplicated these experiments, with similar results.[a] In addition, in order to determine the relative effects of the work of nymphs and adults, some of the former were sent from Idaho and caged with twelve seedling beets, the largest of which was not more than 6 inches in leaf spread. Two days after placing these nymphs in the cage the inner leaves of two beets had begun to curl; in three days three and on the eighth day four plants exhibited symptoms of the disease. At the end of sixteen days but four plants showed curl in a cage in which adult hoppers had been imprisoned. On the fifteenth day all of the plants infested by the nymphs had decided curly-top symptoms. Thus it is shown that the nymphs are more virulent than the adults.

In addition to the varied conditions under which these experiments were made, a further set of conditions was introduced in the field. A portion of two rows of sugar beets was covered with a white muslin awning about 15 inches high. The plants under this awning finally thrust their leaves against it and became badly crowded and the soil remained comparatively wet, yet the disease appeared on these plants in about the same ratio as on those in the open field.

HISTORY OF AN OUTBREAK OF CURLY-TOP IN THE EXPERIMENTAL FIELD AT GARLAND, UTAH.

In the experimental field at Garland, Utah, beet seed was sown on April 14 and the few days following. This is some two weeks later than the average in this locality. In a small plat, separated from the main portion of the field by an irrigating ditch running east and west, were sown several strains of seed from beets grown for several

[a] Grateful acknowledgment is made of the valuable assistance of Dr. C. O. Townsend and Misses N. A. Brown and C. O. Jamieson in conducting the cage experiments in the greenhouse at Washington, D. C.

generations in very alkaline soil and known, on that account, to be much less vigorous than standard varieties sown in the main portion of the field. These weakly strains occupied all of the small plat except four rows next to the ditch; the four rows comprised strains of about ordinary vigor. On May 4 a small proportion of these weakly seeds had sprouted; the weather continued cold and dry and the seedlings were much retarded. On May 20 a few beet leafhoppers were noted on this plat. By June 13 all of the beets had been thinned. On June 27 eighteen cases of curly-top had developed among the first few rows farthest from the ditch. The beet leafhoppers appear to have started their invasion on that side, but at this date they had become fairly well distributed over the plat.

On July 9 ninety-five cases of curly-top had developed; these were mostly confined to the part of the plat where the hoppers started. These insects were now rather abundant.

On July 20 the number of plants showing visible signs was the same as on the 9th. Beet leafhoppers had greatly increased in number and were working over the entire plat. On the side nearest the ditch the beets had become well established and of good size. After this date the symptoms developed very rapidly, until on August 10 there were over three hundred cases.

About mid-October, when the beets were dug, only a small percentage of them was free from signs of the disease. Every plant had then been for some time infested by the insects.

Early in August the leafhoppers had spread over the entire field, but, except for a few cases on the edge of the ditch opposite the badly affected plat, practically no plants in the main field exhibited visible symptoms of curly-top. Few leafhoppers could be found in adjacent fields or in the surrounding district, and cases of curly-top were rare in those fields.

The spring weather was unusually backward, with cold, driving, winds through May and the greater part of June. The sky remained overcast and light showers were frequent during the greater part of this period. Until about mid-May only 0.15 inch of rain had fallen, and the ground had become very dry. During the latter part of May 2.69 inches of rain fell; during June, 3.28 inches. This was distributed in frequent showers of little weight. The strong, cold winds soon dried up this moisture. It was not until July was well advanced that really hot weather set in. During that month but 0.34 inch of rain fell.

EARLY SOWING ADVANTAGEOUS IN PREVENTING CURLY-TOP.

Since it appears that very young beets or those in any way retarded or rendered weakly are more likely to succumb to attacks of

leafhoppers, and since well-established beets show a decided resistance to these attacks, it is obvious that anything assisting the establishment of a vigorous and early stand of beets will at least render much less severe the effect of an invasion of the beet leafhopper, should that chance to occur. The plants may even entirely fail to develop curly-top symptoms in the latter contingency, though they will inevitably be checked in growth. However, should these insects be very numerous and no means of speedily destroying or driving them away be devised and put in operation, the beets, however large and vigorous, will finally succumb.

A striking instance of the advantage of early planting is the following: Out of 13 acres of a single field, 10 were sown with beet seed between April 10 and 15, the remaining 3 acres not being sown until between May 10 and 20. Beet leafhoppers were abundant there that season. The beets planted in May became so badly affected with curly-top that only $2\frac{1}{3}$ tons of beets per acre could be harvested. From the 10 acres planted in April, 16 tons per acre were harvested, few of the plants showing curly-top. The same kind of seed was used and the same cultural methods, irrigation, soil, etc., prevailed over the entire field. The disadvantage of late sowing and poor seed is shown in the case recited as occurring in our small plat.

EXTRACTION OF PLANT JUICES NOT SUFFICIENT TO ACCOUNT FOR THE DISEASE.

That the profound disturbances induced in beets affected with curly-top are not alone due to the extraction of plant juices by leafhoppers seems obvious. A plant like the beet is able to withstand the loss of much more juice than could be extracted by the few leafhoppers that are necessary to induce a bad case of curly-top. The writer saw hundreds of such insects as aphides and red spiders on beet leaves, and the only apparent effect was a local leaf-curl, with discoloration of the parts attacked, but no general and persistent disturbance of the plant as a whole, except when the entire plant was almost covered with these insects, in which case the plant was severely checked and each infested leaf curled. But new growth on such a plant is about normal if the insects are removed. The work of but one leafhopper for a few minutes on a young beet has been shown to be capable of inducing the curly-top symptoms. It therefore seems obvious that some active agent is left in the plant tissues which is capable of initiating profound disturbances.

The writer has observed the symptoms only in growing tissue, and not in mature leaves. Apparently all division is strongly inhibited. This inhibition seems to operate unequally, for, though the growth of the leaf as a whole is checked, the vascular bundles seem to be held back more than the parenchyma between the vascular

bundles; the latter soon swells out between the larger veins and produces the "savoyed" effect so frequently noted. To the naked eye no puncture is visible, nor is any local discoloration due to the punctures to be seen by reflected light, as may be seen in the case of other species of hopper—for example, *Eutettix strobi* Fitch, which leaves a crimson-lake spot at the site of every puncture. However, on careful inspection the writer has been able to discern a faint mottling of green with lighter green in the parenchyma of the leaves of young beets by transmitted light when the curly-top symptoms were developing.

In some badly infested beet fields in Idaho the writer has observed leafhoppers feeding on the dock (*Rumex crispus* L.), and the leaves, especially the inner ones, of all such docks were thickly besprinkled with small, wine-colored, circular spots. These spots coalesce when very numerous in a small area, and if they appear on the petioles and veins the discoloration runs some distance along the fibro-vascular bundles. As these leaves get older they become suffused with red in the more spotted area (Pl. I, fig. 2). The same phenomenon has also been noted in mangel-wurzels, or stock beets, infested by the leafhopper.

CONDITIONS FAVORING AN OUTBREAK OF CURLY-TOP.

It has been stated by several observers that dry, hot seasons seem favorable to severe outbreaks of curly-top, either because such conditions are favorable to the activity and multiplication of the leafhoppers or because detrimental to an early and rapid growth of the beets, or a combination of both. It appears that a cold, dry, backward spring, when the seed is slow to germinate and makes a still more tardy growth after germination, is particularly favorable to an outbreak of the disease. While it may prove true that hot, dry weather stimulates the activity of the insects and renders the development of the disease more rapid and severe, it does not yet appear to be established that to keep the soil about the beets in a moist condition will prevent the insects from invading them, from multiplying, or from producing the disease. However, some leafhoppers may be drowned during an irrigation, but the reduction in numbers thus brought about is not considered of much avail.

Our experiments during 1908 and 1909 show that leafhoppers are able to work and induce the disease under conditions extremely varied, both as regards temperature and actual and relative humidity. The crucial point seems to be the number of leafhoppers infesting the beets in relation to the size and vigor of the plants. There is little doubt that the weather has an important bearing on the matter, mainly, it is thought, on account of its influence on the growth and consequent resisting power of the beets; also quite possibly on ac-

count of its influence on the leafhoppers. Everything considered, there is good reason to urge early sowing of beets in order to get the plants well established before leafhoppers become numerous.

NATURAL AND ARTIFICIAL BARRIERS TO LEAFHOPPER INVASION.

The writer's observations as to the disposition and manner of beet leafhopper invasions lead him to think that certain natural and artificial barriers check or prevent the invasions. For example, the intervention of a considerable area of land occupied by crops not known to act as food plants to the beet leafhopper probably acts as a more or less effective barrier to an invasion, while land immediately contiguous to a wide stretch of sagebrush country is likely to be invaded any season when the hoppers are abundant. It is thought that the intervention of a mountain or a large body of water will act as a barrier and that the direction of the prevailing winds has an influence. Until late in the season of 1909 the writer had not observed the symptoms of curly-top on other plants than beets, but in northwest Idaho he noted numerous leafhoppers on cabbages growing between two badly infested beet fields. The outer leaves of a few of these cabbages exhibited unmistakable vein symptoms and marginal leaf-curl (Pl. IX, fig. 2).

HOST PLANTS OF EUTETTIX TENELLA.

While there is still some doubt as to the original host plants of *Eutettix tenella* Baker, it is rather probable that the principal ones are greasewood (*Sarcobatus* sp.), sea-blite (*Dondea* sp.), *Atriplex* sp., and Russian thistle (4, 5, 6). The writer has found the insect on *Sarcobatus* sp. and *Atriplex* sp. This insect seems to be native to the southwestern part of the United States (4, 6).

DESCRIPTION OF THE BEET LEAFHOPPER.

The beet leafhopper (*Eutettix tenella*) (Pl. I, fig. 1) is very generally, though erroneously, known in the Western States as the "white fly." The white fly, properly so called (*Aleyrodes citri* R. and H.), is a quite different insect and a common pest of citrus trees. The name "white fly" is doubtless somewhat descriptive of the general appearance of the insect, which is of a light yellowish green tint, looking white at a little distance. In size it is almost exactly one-eighth of an inch long and about one-thirtieth of an inch wide. The nymphs vary in size from but little larger than the egg to almost adult size, according to age; their range of color is almost as great

as that of their size. More commonly they are of a creamy white, with irregular areas of brown about the abdomen. These brown areas vary greatly in the amount of pigmentation, so that in general appearance the color ranges through pale cream, buff, light reddish brown, and deeper and deeper browns until some seem almost black; a few have distinctly red markings.[a]

Several other species of leafhopper commonly found on beets closely resemble *Eutettix tenella* in size and color, and few but trained entomologists can readily distinguish between them.

The beet leafhopper is single brooded and begins to deposit its tiny white eggs in the stems and midribs of beet leaves from about the end of June—the time doubtless varying somewhat with the locality and local climatic conditions—until the end of August. Probably the majority of the eggs are deposited by the middle of July. The nymphs begin to appear about the second week in July, and the writer has observed their appearance in considerable numbers in Idaho as late as the end of August. Slit-like scars are produced on the beet stems where the eggs have been deposited; sometimes these ovipository scars are very numerous and conspicuous. The egg stage appears to last about fifteen days, and the young insects reach the adult stage in about twenty days more. These adults hibernate and resume their activity the following spring. In Utah and Idaho they have been seen on weeds in May and on beets near the end of May or early in June. The greater portion of the nymph stage appears to be spent among the inner leaves and petioles of the plant, where the egg is hatched, and as the insect approaches the adult stage it gradually works outward.

The beet leafhopper is an exceedingly active insect; its favorite mode of locomotion is by hops of lightning-like rapidity. The range of its leap seems to be about 18 inches. The adult while on beets uses its wings but little. In common with several closely related species it is a true sucking insect; it is provided with powerful head parts and a stout bill. The latter when not in use is tucked snugly against the under side of the body.

The writer is indebted to Dr. E. D. Ball for much of the data in regard to the life history, habitat, host plants, etc., of the leafhopper, and would refer the reader to the works of this writer for many interesting details and technical descriptions (4, 5, and 6).

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[a] A discussion of this species is given in Bulletin 76, Bureau of Entomology, and a brief practical discussion entitled "Preparations for Winter Fumigation for the Citrus White Fly" in Circular 111 of the same Bureau. The latter may be obtained free on application to the Secretary of Agriculture.

BEET GROWERS SHOULD BE ABLE TO RECOGNIZE THE LEAFHOPPER.

It seems highly desirable that beet growers and field superintendents should be able to recognize the beet leafhopper, so that its earliest appearance may be noted. If successful preventive measures shall be devised, it is very essential to be promptly informed of the first appearance of leafhoppers in considerable numbers, so that such devices may at once be put in operation. It has not been shown that any other species of leafhopper is able to induce the curly-top symptoms, though both Doctor Ball and the writer have independently experimented with other species commonly found on beets.

SERIOUS NATURE OF CURLY-TOP.

The serious nature of curly-top may be understood when it is known that in some localities practically the entire sugar-beet crop has been destroyed. The writer has seen fields of beets completely denuded by it. Furthermore, beets that do produce a root of fair size because attacked comparatively late in the season possess a high percentage of impurities and are on that account not so desirable to the sugar companies.

It may be said that beets once affected with curly-top never recover. Even when the affected foliage is cut back repeatedly at intervals of several weeks, the new growth exhibits unabated symptoms (29).

A CONSIDERATION OF CURLY-TOP IN SEED BEETS.

It has been observed by those who have raised beet seed in the regions subject to the scourge of curly-top that a variable percentage of seed beets will manifest symptoms of the disease with the first shoots to appear in the early spring. This has been noted by several members of the Office of Sugar-Plant Investigations and by Doctor Ball (6).

The following specific cases are good illustrations: In addition to the cases of curly-top observed in June, 1907, among sugar beets (see p. 13), the writer noted a fair percentage of seed beets thus affected, but at that time little special attention was given the latter. It was merely assumed that they might have contracted the disease at the same time and in the same manner as the sugar beets, however that might have been. No sugar beets exhibiting visible signs of the trouble were selected for siloing in the fall of 1907. Among those selected for use as seed beets were some of the pedigree and garden beets referred to as showing a large percentage of curly-top, together

with a considerable number of apparently healthy beets of standard varieties.

The silos were opened April 10, 1908, and the beets were planted April 10, 11, and 13 in the experimental field at Garland, Utah. Within ten days they began to sprout. In the meantime the weather was very severe, with great extremes of temperature. On May 24 most of these beets had sprouted, and many of the pedigree beets showed suspicious signs of curly-top. The closest scrutiny failed to reveal the presence of leafhoppers at this time. On May 14 a canvass of the entire plat of seed beets showed the trouble to be more widespread than at first supposed, though even at this date no leafhoppers had been seen. By May 20 one portion of the pedigree beets showed signs of the disease to the extent of 48.67 per cent, and another portion 29.36 per cent, as against 3.87 per cent among the standard varieties. At this time a few beet leafhoppers had appeared on the small plat that later became so badly affected. On June 8 the percentage of plants visibly affected was 52.21, 58.54, and 17.19, respectively. The writer could not assign the cause of the outbreak among the seed beets to the few leafhoppers then in evidence. Indeed, the first cases of curly-top did not appear among seedling sugar beets in the plat mentioned until about three weeks later, when the insects had become much more numerous.

The experiments hitherto described in connection with the work of the beet leafhopper on sugar beets, whereby this insect was shown to be the primary causative agent of curly-top, together with the observations just set forth, led to the conclusion that the disease may be initiated in the seed beets by the hopper during the season preceding their use for seed production. In order to determine this point conclusively it was arranged to take advantage of the outbreak of curly-top in the small plat during 1908. To this end there were selected from this plat about one hundred beets of good size and shape that at the end of the season exhibited no visible signs of the disease; also, one hundred similar beets showing well-developed symptoms of the trouble were selected from the same plat. All were carefully siloed for planting in the spring of 1909. Many beets were also siloed from the major portion of the field, where but few cases of the trouble had appeared, though these latter plants had been infested by leafhoppers during the later part of the season.

Very early in April, 1909, these beets were planted out in the usual manner. From the moment of planting, close watch was kept for leafhoppers of any species. Almost with the first appearance of the shoots of the seed beets from the affected plat of last season, whether or not the beets had then exhibited symptoms of curly-top, the characteristic curl and vein symptoms appeared. On May 24 all those

beets showing curly-top when harvested at the end of the preceding season had again developed the symptoms. Of those showing no symptoms when harvested, 83 per cent were affected on the same date. Later in the season but 2 per cent of this latter batch was free from visible symptoms of the disease, and even the 2 per cent was

FIG. 7.—Mature healthy seed beet. (For comparison with seed beets affected with curly-top.)

checked in growth. Of the large number of beets siloed from the major portion of the field, where practically no cases of the disease had appeared during the preceding season and which were planted out at the same time in the spring for seed production, about 10 per cent had developed curly-top on May 24. It will be remembered that no leafhoppers appeared until May 20, and then but few.

The same spring some of the standard varieties of seed beets (see fig. 7) were planted at Central Farm, about 6 miles from our experimental field at Garland; other lots were planted at North Farm, about 1½ miles away; at Corinne, about 16 miles away, and at Lehi, about 100 miles distant. At these places it was difficult to find a single beet leafhopper during the entire season. Nevertheless, a like percentage of curly-top appeared among the beets planted at each place. Furthermore, there had been planted at Corinne some of the apparently healthy beets from the badly affected plat at Garland. All these manifested the characteristic signs of the disease very early. Numerous seed beets were sent from Fairfield, Wash., and planted at Central Farm in the plat with those just referred to. Among these no curly-top appeared. No beet leafhoppers could be discovered at Fairfield the preceding season.

FIG. 8.—Sugar-beet seed stems showing curly-top symptoms. These stems had been denuded of all but single-germ seeds and a few bracts; the new growth alone exhibited curly-top symptoms.

During the same spring some beets were sent from Garland to Compton, Cal., to be planted there as seed beets. Most of these developed curly-top, although no leafhoppers could be found at Compton. None of the factory beets or seed beets grown there became affected.

These results go to show that the changes set up by beet leafhoppers are profound and persistent and that while a beet may have been resistant during its first season to the extent of growing to about normal size without exhibiting signs of the disease, some reaction has been initiated that will show itself in the manner characteristic

of curly-top the following spring if the beet is planted for seed purposes.

Of seed beets the writer could never observe that plants as a whole ever succumb to the attacks of the leafhoppers during the season they are planted as seed beets. They are too vigorous and resistant, and nearly all the leaves are full grown before beet leafhoppers appear in number. However, individual shoots and racemes put forth late in the season may manifest the symptoms if attacked by leafhoppers (fig. 8). Then, too, the entire aftergrowth, which generally develops late in the summer, after the seed has been harvested, may exhibit pronounced signs of the disease. This actually occurred on the plat at Garland after the seed harvest of 1908, when the aftergrowth of nearly every seed beet became thus affected. This aftergrowth consisted of actively growing and immature leaves in which cell division was taking place.

The symptoms are generally more diverse in seed beets. Apparently the element of greater resistance on account of greater size and vigor is a factor tending to the production of symptoms not commonly noted in young sugar beets. However, these additional, and among sugar beets less usual, symptoms may be seen in sugar beets when quite large plants are attacked by so many leafhoppers that even they finally succumb. These symptoms are those mentioned as the retracted type.

The writer has been able to produce the retracted curl under test conditions by imprisoning a gradually increasing number of leafhoppers with beets that would ordinarily fail to develop the symptoms on account of their size when attacked by the insects (see figs. 2 and 3).

SEVERAL TYPES OF LEAF-CURL ON SEED AND SUGAR BEETS.

As a result of observations on the development of the disease in seed beets the writer has been able to note several types of symptoms on them, as follows:

(1) The type most commonly noted on sugar beets and hitherto regarded as the characteristic appearance of beets affected with curly-top, viz, with leaves strongly curled inward from the entire margin toward the midrib; strongly knotted veins; thickened parenchyma, which in advanced stages is quite brittle, though tough and leathery in appearance; very dark and dull green foliage with outer whorls sear and dead; pronounced inhibition of growth; early appearance of feeble seed stem, which sometimes does and sometimes does not mature seed. (See Pl. I, fig. 1; Pl. II, fig. 1; Pl. IV, fig. 1; Pl. VI, fig. 1; and Pl. IX, fig. 1.)

(2) The type with short, ovate, retracted leaves and short, bowed petioles; tissue between larger veins puffed out as though the parenchyma had outgrown the fibro-vascular tissue; veins generally rather less knotted than in the preceding type; generally the early appearance of abortive seed stems; almost entire inhibition of growth after first month. This type is perhaps the most abundant one among seed beets and is found also on sugar beets that succumb late in the season after attaining a considerable size. (See Pl. III, fig. 1, and Pl. V, fig. 1.)

(3) The type with long, narrow, sinuous, thick, leathery-looking leaves; without marginal curl or vein symptoms; no seed stems; almost entire inhibition of growth after first month or six weeks; dull, dark-green foliage, inclined to russet. (See Pl. IV, fig. 2.) Noted only on seed beets.

(4) The type with small rosettes of leaves similar to those of the second type mentioned, but much smaller; very early cessation of growth; no seed stems; very feeble vitality, yet root apparently quite solid and crisp. (See Pl. V, fig. 2, *B*.)

(5) The type with root apparently as sound and crisp when planted as the most healthy beet, yet making no growth at all.

(6) The type with part of shoots affected with marginal curl, inward; growth not otherwise seriously affected; part of shoots apparently normal.

(7) The type with no visible symptoms of the disease, but general growth checked. (See Pl. VI, fig. 1.)

(8) Combinations of any of the foregoing. (See Pl. V, fig. 2, *A*.)

AFFECTED SEED BEETS ALMOST NONPRODUCTIVE.

The serious nature of curly-top is heightened by the fact that few seed beets affected by it produce seed. Of those possessing sufficient vitality to produce seed stems, many dry up and die before maturity; the very few that produce seed are so puny and stunted as to produce but a small fraction of a normal yield. Thus, it will be seen that, while this species of leafhopper is a serious menace to the sugar-beet crop, it is doubly so when beets are raised for seed. The beets may be quite satisfactory for the manufacture of sugar and appear normal and healthy when harvested, yet have stored within them an active agent that may cut down the seed crop from a few per cent to entire loss.

PERCENTAGE OF LOSS OF SEED BEETS.

When put in plain figures this loss is very striking. To revert to the experiment just mentioned, those plants showing no curly-top

when siloed produced an average of only 13.82 grams of seed; those exhibiting signs of the disease when harvested produced but 13.25 grams per plant. The average for the healthy beets was about 375 grams, or about twenty-eight times as much as the yield of affected plants. (See fig. 9.)

During 1905 an important sugar-beet district was afflicted by an invasion of *Eutettix tenella* which resulted in great loss. The sugar company, however, selected and siloed enough apparently healthy beets to plant 4½ acres in the spring of 1906 for seed production. Of these, 1½ acres were entirely unproductive; only 1,200 pounds of

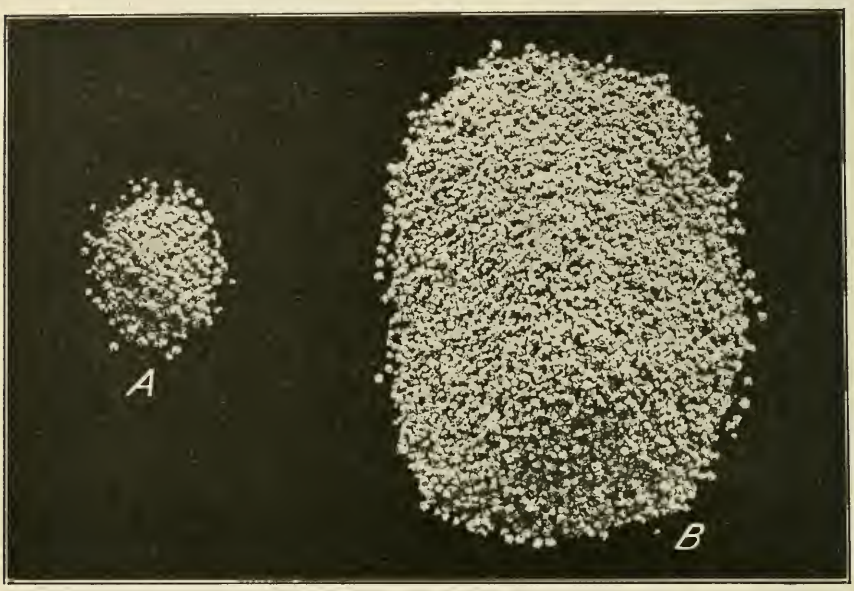

FIG. 9.—Average seed yield of healthy and curly-top sugar beets: (*A*) Average amount from diseased beets, 13.25 grams; (*B*) average from healthy seed beets, 375 grams.

seed were obtained from the other 3 acres, or 400 pounds to the acre, or 36.3 grams per plant. In 1906, when the sugar-beet crop was good in the same district and few leafhoppers appeared, enough beets were selected to plant 8.29 acres. These seed beets yielded 16,800 pounds of seed, or 2,038.6 pounds to the acre, or about 177.6 grams per plant. The difference here shown is not so great as in the experiment conducted by the writer because not all of the beets siloed by the sugar company could have been as severely attacked during the preceding season; then, too, the plants used by the writer were set much farther apart than those of the sugar company, thus encouraging a larger yield among the healthy beets.

SEVERE OUTBREAKS NOT FREQUENT IN A LOCALITY.

A notable feature of curly-top is that, so far as has been recorded, there never has been a serious outbreak two seasons in succession in any locality. Therefore, the farmer may be encouraged to continue the culture of sugar beets in spite of the heavy loss consequent on a single attack. This opportunity is taken, however, to utter a note of warning to seed producers to the effect that it will be unprofitable to silo sugar beets harvested from an area badly affected with curly-top, even though no beets exhibiting the characteristic symptoms are selected for siloing. Furthermore, should the beet leafhoppers be numerous without producing more than a sprinkling of plants showing visible signs of the disease, a more or less considerable percentage of loss may be expected through the development of the disease in seed beets the following season. The probable amount of loss will obviously depend on the number of leafhoppers present during the preceding season, together with the general vigor of the plants at that time and the length of time the leafhoppers had been at work on the beets.

PROGENY OF THE DISEASED SEED BEETS HEALTHY.

Another strange feature of curly-top is that the seed from an affected seed beet will produce healthy sugar beets, which in turn afford vigorous and healthy seed beets unless in the mean time they are attacked by more leafhoppers. Thus it appears that seed from affected beets need not be discarded on account of the disease.

GENERAL CHARACTER OF CURLY-TOP.

It would appear from these observations and experiments that the curly-top of beets should be included in the group of plant disturbances known as "stigmonoses," as described by Dr. A. F. Woods in connection with the effects of aphides, thrips, and other sucking insects on the carnation (32, 33, 34, 35, 37), by Dr. N. A. Cobb as occurring on apples, pears, etc. (10), and by Moulton as occurring on the pear (21). Curly-top resembles these stigmonoses in that the disturbances are primarily set up by the punctures of sucking insects—the beet leafhoppers. In certain varieties of beets and in docks punctured by the beet leafhopper, discoloration and spotting of the leaves follow the punctures of these insects, and in young sugar beets a faint mottling of the attacked leaves may be noted by transmitted light (see p. 10); leaf distortions, though differing in character and extent, are common to both. In the case of stigmonose, Woods has shown that when the abnormal changes due to aphis punctures "have

once been started in a plant the ill effects continue long after the initial cause has disappeared. If the insects are killed or kept off such a plant the new growth will be free from spots and therefore apparently healthy. It is, however, poor in reserve albumin and has an excessive amount of oxidizing enzyms * * * and is therefore in fact diseased. This malnutrition becomes gradually cumulative from generation to generation of cuttings, and so far as our investigations have gone, can not be cured." In this respect the behavior of curly-top beets is almost identical, the most noteworthy difference being the persistence of the visible symptoms in all new growth of curly-top beets, even after repeated cuttings back of the foliage at intervals of several weeks.

In the cases described by Woods and others the visible effects of the insect punctures are confined to the leaf, or even the portion of the leaf, attacked, whereas, as just stated, the disturbance induced in the curly-top beet affects the whole plant in such a manner that all of the growing foliage shows visible symptoms of the disturbance.

While curly-top is initiated in the same manner as stigmonose and so far as can be discovered (29) can not be attributed to bacteria or fungi, the physiological disturbances seem to bear a close resemblance also to those described by Woods and others (7, 15, 18, 19, 20, 23, 24, 25, 34) as mosaic. In the case of curly-top it is true that the rather conspicuous leaf mottling noted in the mosaic disease is absent, except for the faint mottling already referred to as occurring in leaves of young beets affected by curly-top and visible only by transmitted light. On the other hand, the general nutritional disturbances and the unbalancing of normal enzym activities described by Woods (33) seem to be duplicated in curly-top beets; in the latter, too, there is a similar persistence of visible symptoms. Still another feature is common to both the mosaic disease and curly-top, viz, under both conditions an affected plant will sometimes yield seed, and in each case that seed is capable of producing normal, healthy plants.

The writer has not yet secured conclusive evidence that these symptoms can be induced in beets by the methods practiced by Woods (34) in the case of the mosaic disease. Indeed, it would appear to him difficult to do so, for the reason that the beet root contains so large a reserve of nutrients. Townsend's experiments (29) and some conducted by the writer seem to negative the idea, but further investigations along this line are necessary. However, the writer is of the opinion that there is a striking resemblance in the general behavior of curly-top beets to that of those suffering from the mosaic disease.

This would indicate that curly-top is the most conspicuous and destructive form of stigmonose and, at the same time, one of the

most interesting to the pathologist and physiologist on account of the profound disturbances set up, as well as from its apparent relationship to the mosaic disease. Apart from curly-top the writer has noted stigmonoses of the sugar beet which are identical with those described by Woods, Cobb, and Moulton, as well as with others caused by different species of leafhoppers.

SUMMARY.

The curly-top of beets is related causatively to stigmonose; pathologically and physiologically to both stigmonose and the mosaic disease. It manifests itself through numerous external and internal symptoms of diverse character.

The aggregate of these symptoms presents an appearance characteristic of this disease, though taken individually all except the vein symptoms have been noted under other conditions.

Two distinct types of curl are manifested in this disease—the inward and the outward, or retracted.

The symptoms are essentially alike in factory and seed beets. Among seed beets there is a larger proportion of the retracted type.

The beet leafhopper (*Eutettix tenella* Baker) is the primary cause of the trouble; no outbreaks are known to have occurred outside of the native habitat of this insect, viz, the Southwestern States, generally in the vicinity of what is known as "sagebrush country." The plants named as the probable host plants of the beet leafhopper are found where outbreaks of curly-top have occurred. The insect probably migrates from those plants to beets.

One leafhopper is capable of initiating the disturbances in a young beet, and the effect of numerous hoppers on seedlings may be so severe as to kill them in a few days, before the visible symptoms have had time to develop. The younger the beet the more sensitive is it to leafhopper work.

The nymphs of *Eutettix tenella* produce the symptoms of curly-top much more rapidly than do the adult insects.

No other insect and no other species of leafhopper is known to induce the disease herein described.

Though vigorous beets of four months growth or older will offer considerable resistance, any beet will succumb if attacked by numerous beet leafhoppers. Neither is any variety of beet immune.

The symptoms appear only on immature leaves where cell division is still active—never on full-grown leaves. They appear first on the inner leaves just as the latter unfold.

It is considered advisable to plant as early as practicable after danger of late frosts is over, even to take some risks of late frost,

in order to get the beets well established and vigorous before leafhoppers are likely to be numerous.

The disease can not be due to loss of plant juices extracted by leafhoppers, but rather to the introduction by those insects of an active agent.

Few or no beets that develop curly-top symptoms ever recover.

Beets may fail to show symptoms of curly-top to the end of the season if attacked by leafhoppers after they have attained considerable size and vigor. Yet the trouble is initiated and transmitted to the root, only to develop with full virulence in the first shoots the following spring if they be planted out for seed production.

The active agent is therefore persistent and sets up disturbances throughout the whole plant.

It is risky to select for seed purposes any beets from fields badly infested with beet leafhoppers, even though no large number of cases of curly-top appear.

It is useless to make selections for seed from fields badly affected with curly-top.

The inward type of curl is generally produced on young beets. The retracted type appears on seed beets and on sugar beets that had attained considerable size and vigor before the symptoms developed.

Until recently curly-top symptoms had been noted on no other plants than beets, but the writer noted the symptoms on cabbage in 1909.

The punctures of the beet leafhopper produce wine-colored stains on the leaves of dock (*Rumex crispus* L.) and on stock beets, but no such discoloration has been observed on sugar beets.

Anything tending to retard or weaken beets renders them less resistant to leafhopper attacks.

The leafhoppers can induce the symptoms of curly-top under extremely varied conditions of moisture, temperature, and atmospheric pressure.

Weather, soil, etc., may influence the severity of the disease indirectly by modifying the vigor of the beets; possibly, also, the leafhoppers are influenced favorably or otherwise by varying weather conditions.

If seed beets are really healthy when planted—that is, if they have not been subjected to the attacks of leafhoppers during their first season's growth—there is little chance that they will succumb to leafhopper attack during their season as seed beets. An attack involving the whole seed beet is perhaps without exception the result of attacks during the preceding season, though no symptoms may then have appeared. Portions of the later shoots and the aftergrowth of

leaves following the seed harvest have frequently been known to develop the symptoms.

Few affected seed beets are capable of producing seed, and then only in very small quantity. The seed yielded by affected seed beets will, however, produce healthy sugar beets, which, in turn, unless in the mean time attacked by more leafhoppers, are capable of becoming good seed beets.

It has not been found possible to communicate the disease from an affected plant to a healthy one.

CONCLUSION.

In cooperation with the Bureau of Entomology, the writer has already carried on some spray experiments in the hope of devising a method of holding the destructive beet leafhoppers in check. It was found that, if it can be thoroughly applied to the insects, a strong kerosene and whaleoil-soap emulsion will kill them. However, the time is so short when the spray might efficaciously be applied that it is not yet certain that spraying will be practicable. Then, too, it is not easy to apply a spray to the beet leafhopper, because its wings thoroughly protect its body and thus prevent the emulsion becoming effective.

Possibly some form of "hopper-dozer" used at the right time will prove more serviceable. More experimental work is needed along these lines.

At the suggestion of the Bureau of Entomology, the following recommendations, found in Bulletin 66, Part IV, of that Bureau, pages 47–48, are quoted:

> More should be known about the places of hibernation and early spring history of this insect. It could not be found in the rubbish around the fields in early spring, and only a few specimens were found in waste places up to the time they appeared on the beets. When once the place where the greater number of them pass the winter is discovered, it may be possible to destroy them there or on their spring food plants before they migrate to the beets. After they have appeared on the beets it will be necessary to be very prompt in the matter of remedies if the injury is to be prevented. A thorough spraying with kerosene emulsion at a strength of 1 part of the stock solution[a] to 5 parts of water would destroy most of the insects that it hit, and by using a drag in front of the nozzles to turn the leaves over and cause the insects to jump, most of them could be reached. Where the insects were coming in in numbers this spray would need to be followed by a second one ten days later.
>
> Several mechanical devices have been used to catch different leafhoppers, and no doubt several of these could be used against this insect with advantage. The tar pan, or "hopper-dozer," drawn over the beets two or three times in

[a] For directions regarding the preparation and use of kerosene emulsion see Farmers' Bulletin 127, U. S. Dept. of Agriculture, pp. 20–21, and Circular 80, Bureau of Entomology.

the first few weeks would capture a large number of them. The females, before the eggs are laid, are quite heavy and do not jump or fly as readily as the males and would be easily caught. A modified form of this machine, consisting of a couple of tarred wings to be drawn along on each side of a row of beets, while a drag agitated the tops and caused the insects to fly, would probably capture more than the simpler tar pan.

If the insects appeared while the beets were quite small, they could be largely destroyed by rolling when the weather was cold or damp and the insects sluggish.

A number of preventive measures may be used to assist the beets in withstanding the attack of the leafhoppers. In some sections early planting will produce beets large enough to shade the ground by the time the beet leafhoppers appear, and thus reduce the temperature below the danger line. In a few places, like the Grand Junction district in Colorado and Sevier County in Utah, early planting alone would not avail, as the insects appear soon after the earliest beets come through the ground. For such sections early and frequent irrigations would assist in keeping the ground cool until the beets grew large enough to shade it and thus take care of themselves.

All preventive measures will depend for success upon some method of controlling the temperature in the field so that the ground may not be hot and dry at the time the leafhoppers appear.

RECOMMENDATIONS.

Undoubtedly some of the remedies advised against the hop flea-beetle, an entirely different insect and one which also affects sugar beets, in Bulletin 66, Part VI, of the Bureau of Entomology, pages 83–91, and a supplementary article, Bulletin 82, Part III, on the same species, will be found useful. Particular attention is called to the latter publication, by Mr. W. B. Parker, collaborator of the Bureau of Entomology, as the experiments have been very carefully carried out with the hop flea-beetle, which from its habit of flying quickly and hopping resembles leafhoppers, in that the beetles can be reached in somewhat the same way.

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   Stigmonose of carnations is described under the name "bacteriosis." The disease is regarded as mainly affecting the leaves.

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   These writers verified an appearance of bacteria in the roots of beets affected with a leaf-curl, producing a "savoyed" appearance in the leaves. They were unable to reproduce the symptoms by inoculating with pure cultures of the bacterium.

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   Ball here describes various species of leafhoppers, including the beet leafhopper (*Eutettix tenella* Baker), and from the observed appearance of the latter at the time of outbreaks of curly-top of beets is of the opinion that this insect is the cause of the disease.

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   Ball here holds that the leafhopper (*Eutettix tenella*) is the cause of curly-top.

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This paper describes the isolation of bacteria from roots of beets affected by a leaf-curl.

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Ravaz describes a disease of the vine under the name "Le Court-Noue," which shows all the characteristic markings and symptoms of mosaic disease.

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Woods describes the mosaic disease of tobacco and shows it to be probable that there is a disturbance of nutrition due to a lack of balance in the relative amounts or activity of enzymes, that the oxidizing enzymes seem to be abnormally active in the diseased cells, and that the mode of operation is to weaken or retard the action of the diastase. The action of the oxidizing enzymes upon the diastase, therefore, retards the production of sugar, and consequently of proteids and reserve nitrogen in general. The conclusion is reached that the disease can not be due to parasites, but must be attributed to a disturbance of the normal physiological activity of the cells in question. Whatever causes the reduction of available nitrogenous reserve food, especially soluble nitrogen, below the requirements of dividing cells may cause this disease in the tissues of certain plants.

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This paper contains substantially the matter presented in "Stigmonose, a Disease of Carnations and Other Pinks."

PLATES.

DESCRIPTION OF PLATES.

PLATE I. Work of the beet leafhopper (*Eutettix tenella* Baker). Fig. 1.—Beet leaves affected by curly-top; also a beet leafhopper. (*A*) A beet leaf with inward curl and pronounced vein symptoms; (*B*, *C*) two small beet leaves with retracted type of curl; (*D*) beet leafhopper, adult. Fig. 2.—Dock leaf (*Rumex crispus* L.) spotted by punctures of beet leafhopper. These spots are of dark crimson-lake, punctate but gradually becoming diffuse; on the fibro-vascular bundles they become lanceolate. Natural size.

PLATE II. Work of beet leafhopper on seedling beets. Fig. 1.—Healthy and curly-top sugar-beet seedlings and leaves. (*A*) Healthy seedling; (*B*) curly-top seedling with well-developed hairy-root, bowed petioles, vein symptoms, and leaf curl; (*C*) front view of an inner leaf from plant *B*, showing marginal curl; (*D*) dorsal view of similar leaf, showing vein symptoms. Fig. 2.—Healthy and curly-top sugar beets of medium size. (*A*) Curly-top beet with hairy-root, tough and fibrous root, wide crown with many imperfect leaves sprouting therefrom; (*B*) beet in perfect health.

PLATE III. Effects of leafhopper attacks. Fig. 1.—Large sugar beet affected late in the season by curly-top. The retracted type of curl appears to be produced by leafhoppers when they attack a large beet in considerable numbers. Fig. 2.—Sections of healthy and curly-top sugar beets, showing the discoloration of fibro-vascular bundles. (*A*) Longitudinal and (*B*) oblique sections of a healthy sugar beet, showing the very light, delicately traced fibro-vascular bundles of the root. (*C*, *D*) Similar sections of a curly-top beet, showing the dark areas, dark fibro-vascular bundles, and blackened area with incipient cavity near crown; (*E*, *F*) similar sections of curly-top beet, showing more pronounced blackening of bundles and a cavity with black walls near crown.

PLATE IV. Seed beets affected by curly-top. Fig. 1.—Seed beet exhibiting inward type of curl. Fig. 2.—Seed beet with long, sinuous type of leaves due to curly-top; this type never produces a seed stem.

PLATE V. Seed beets affected by curly-top. Fig. 1.—Seed beet showing retracted type of curl. The greater portion of seed beets thus affected have this type of leaf-curl. Fig. 2.—(*A*) Seed beet showing both inward and retracted types of leaf-curl; (*B*) seed beet with rosette of severely retracted leaves and no seed stem. With this type of curl no seed stem ever develops.

PLATE VI. Seed stems of curly-top beets. Fig. 1.—Curly-top seed beets maturing seed. Fig. 2.—Seed beet slightly affected by curly-top; very slight symptoms of the disease are apparent; the trouble is shown principally in the checking of growth. Compare with Plate VII, which shows a healthy seed beet of the same age photographed to the same scale.

PLATE VII. Healthy seed beet of same age as that shown in Plate VI, figure 2.

PLATE VIII. Root conditions of seed beets affected with curly-top. Fig. 1.—Seed beet badly affected by curly-top and root almost destroyed by rot. (Probably *Phoma betae* or Rhizoctonia.) Rot not caused by the curly-top. Fig. 2.—Seed beet with sound root, though badly affected with curly-top. This root was as crisp and sound as when siloed more than seven months earlier.

PLATE IX. Fig. 1.—Two young sugar beets showing curly-top symptoms under test conditions with leafhoppers. These plants were placed under ½-gallon Mason jars with two to four leafhoppers, and the disease developed as the result of their attacks. Mason jars shown in the background over other beets. Fig. 2.—Portion of cabbage leaf showing curly-top symptoms after leafhopper attacks; no visible spotting of leaves. These cabbages grew in a small plat between two badly leafhopper-infested fields; many leafhoppers were noted feeding on the outer leaves of the cabbages.

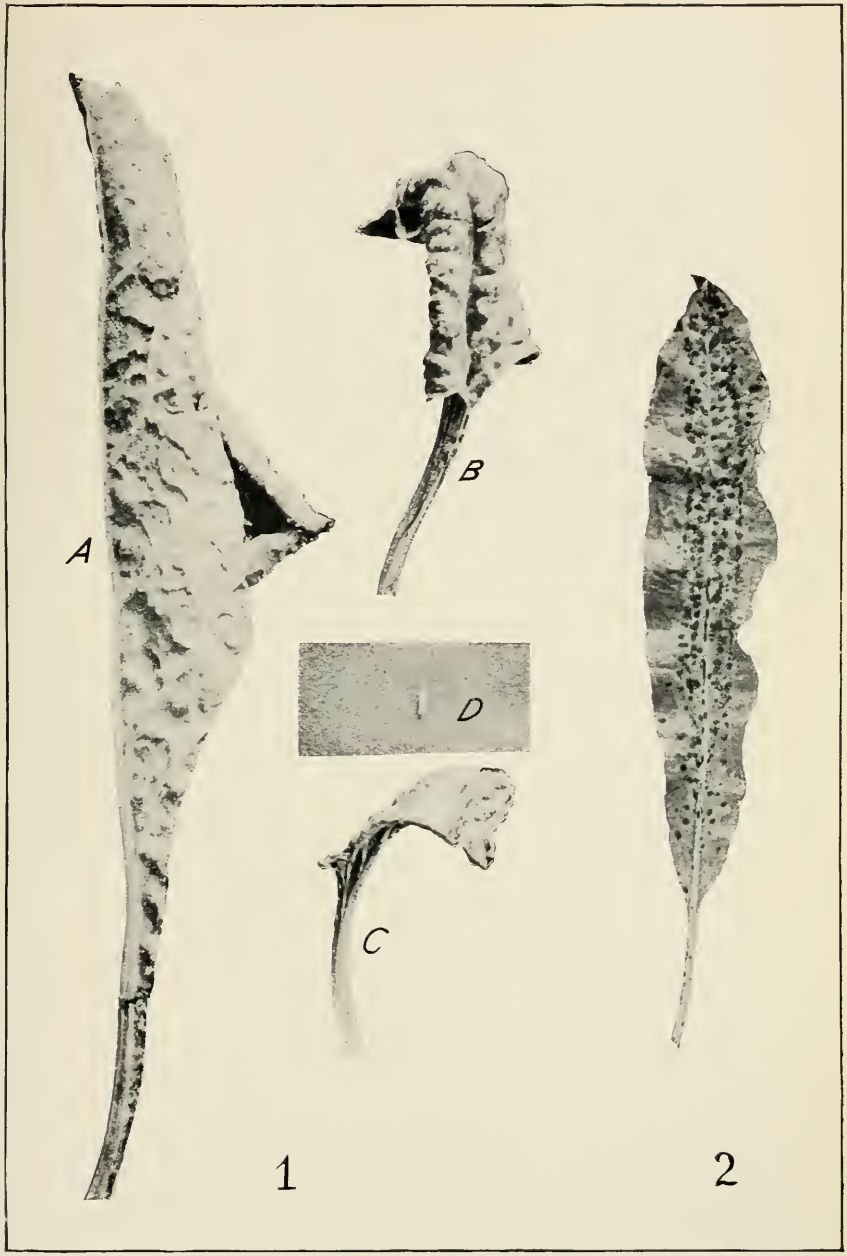

FIG. 1.—BEET LEAVES AFFECTED BY CURLY-TOP (*A*, *B*, *C*); ALSO A BEET LEAFHOPPER (*D*). FIG. 2.—DOCK LEAF SPOTTED BY PUNCTURES OF BEET LEAFHOPPER.

(Natural size.)

Bul. 181, Bureau of Plant Industry, U. S. Dept. of Agriculture.

FIG. 1.—SUGAR-BEET SEEDLINGS AND LEAVES IN A HEALTHY CONDITION AND OTHERS AFFECTED BY CURLY-TOP: *A*, HEALTHY SEEDLING; *B*, SEEDLING AFFECTED BY CURLY-TOP; *C*, FACE OF BADLY AFFECTED LEAF; *D*, DORSUM OF SIMILAR LEAF.

FIG. 2.—HEALTHY AND CURLY-TOP SUGAR BEETS OF MEDIUM SIZE: *A*, CURLY-TOP BEET; *B*, HEALTHY BEET.

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FIG. 1.—LARGE SUGAR BEET AFFECTED LATE IN THE SEASON BY CURLY-TOP.

FIG. 2.—SECTIONS OF HEALTHY AND CURLY-TOP SUGAR BEETS, SHOWING THE DISCOLORATION OF FIBRO-VASCULAR BUNDLES.

FIG. 1.—SEED BEET EXHIBITING INWARD TYPE OF CURL.

FIG. 2.—SEED BEET WITH LONG, SINUOUS TYPE OF LEAVES CAUSED BY CURLY-TOP.

FIG. 1.—SEED BEET SHOWING RETRACTED TYPE OF CURL.

FIG. 2.—*A*, SEED BEET SHOWING BOTH INWARD AND RETRACTED TYPE OF LEAF-CURL; *B*, SEED BEET WITH ROSETTE OF SEVERELY RETRACTED LEAVES AND NO SEED STEM.

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FIG. 1.—CURLY-TOP SEED BEET MATURING SEED.

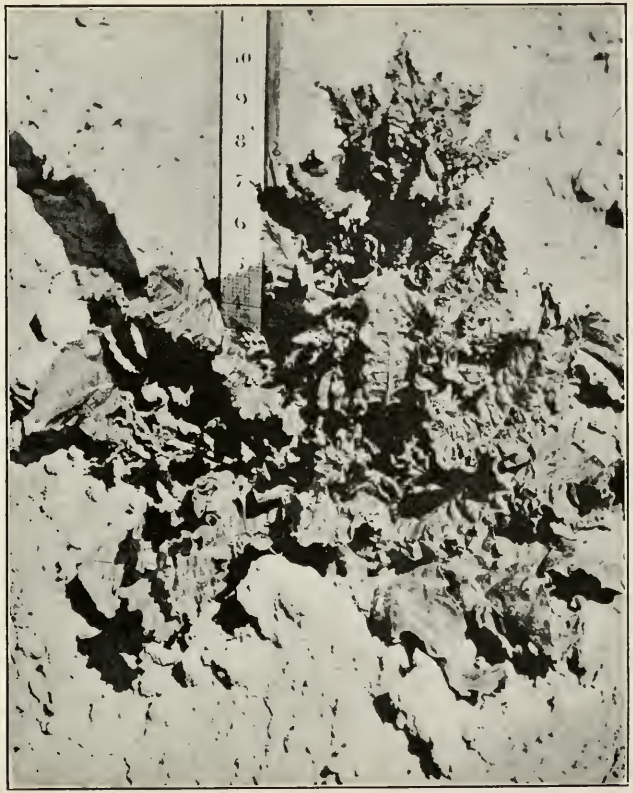

FIG. 2.—SEED BEET SLIGHTLY AFFECTED BY CURLY-TOP.

HEALTHY SEED BEET OF SAME AGE AS THAT SHOWN IN PLATE VI, FIGURE 2.

Bul. 181, Bureau of Plant Industry, U. S. Dept. of Agriculture.

FIG. 1.—SEED BEET BADLY AFFECTED BY CURLY-TOP, AND ROOT ALMOST DESTROYED BY ROT.

FIG. 2.—SEED BEET WITH SOUND ROOT, THOUGH BADLY AFFECTED BY CURLY-TOP.

Bul. 181, Bureau of Plant Industry, U. S. Dept. of Agriculture.

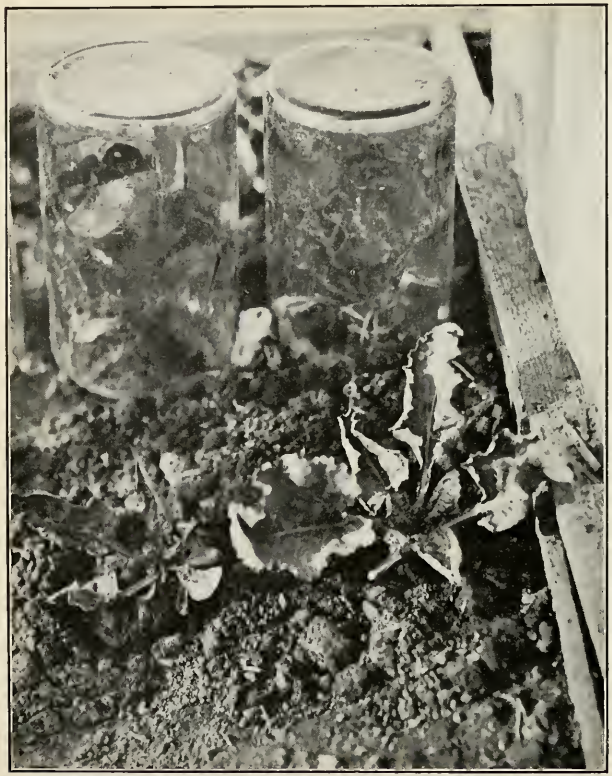

FIG. 1.—TWO YOUNG SUGAR BEETS SHOWING CURLY-TOP SYMPTOMS UNDER TEST CONDITIONS WITH LEAFHOPPERS.

FIG. 2.—PORTION OF A CABBAGE LEAF SHOWING CURLY-TOP SYMPTOMS AFTER LEAFHOPPER ATTACKS; NO VISIBLE SPOTTING OF LEAVES.

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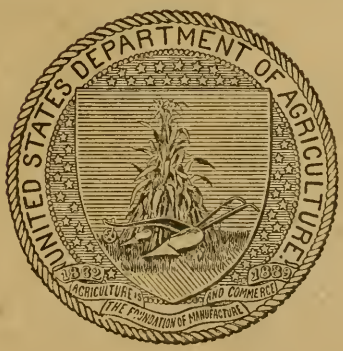
BUREAU OF PLANT INDUSTRY—BULLETIN NO. 182.
B. T. GALLOWAY, *Chief of Bureau.*

TEN YEARS' EXPERIENCE WITH THE SWEDISH SELECT OAT.

BY

MARK ALFRED CARLETON,
CEREALIST IN CHARGE OF GRAIN INVESTIGATIONS.

ISSUED SEPTEMBER 8, 1910.



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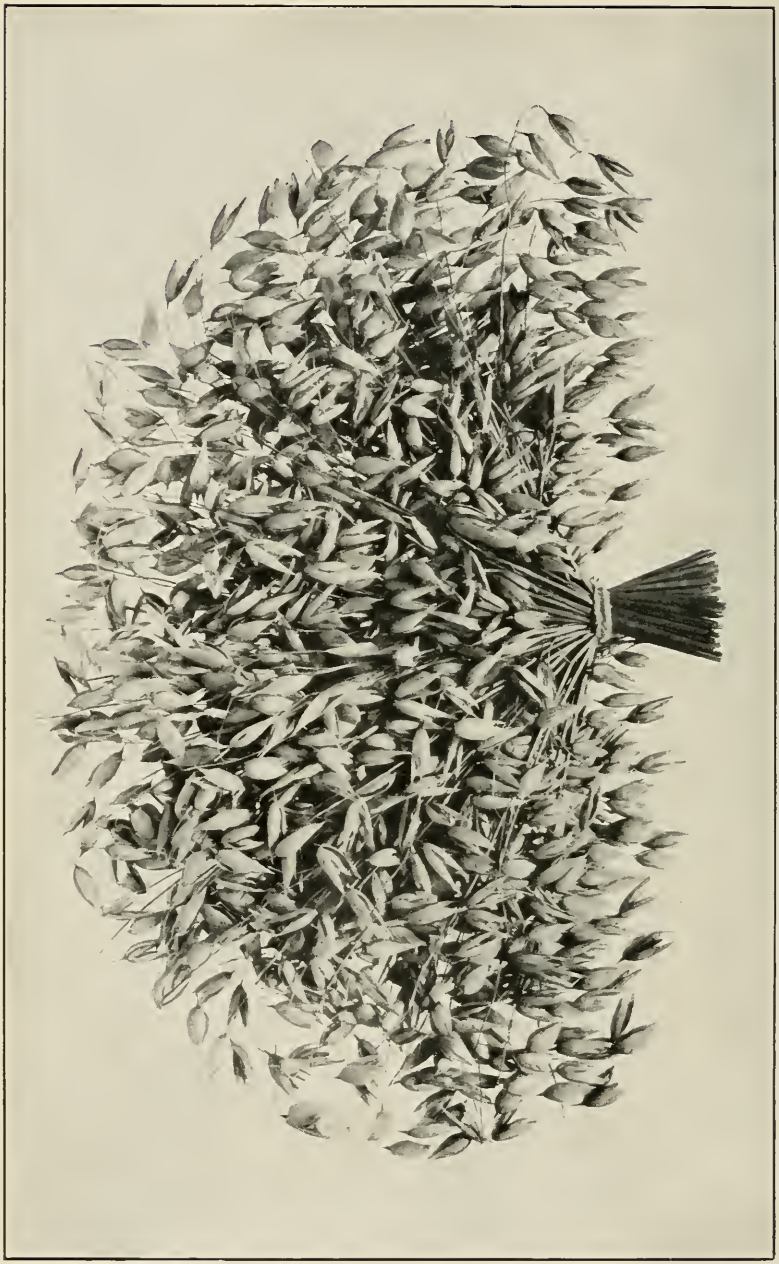

HEADS OF THE SWEDISH SELECT OAT GROWN AT SITKA, ALASKA, IN 1903.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY—BULLETIN NO. 182.
B. T. GALLOWAY, *Chief of Bureau.*

TEN YEARS' EXPERIENCE WITH THE SWEDISH SELECT OAT.

BY

MARK ALFRED CARLETON,
CEREALIST IN CHARGE OF GRAIN INVESTIGATIONS.

ISSUED SEPTEMBER 8, 1910.

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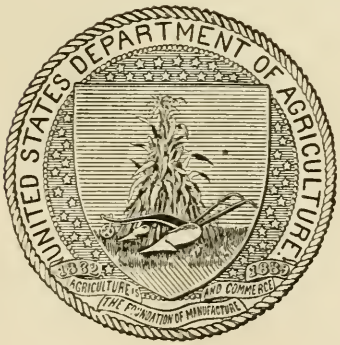

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., March 28, 1910.

Sir: I have the honor to transmit herewith a paper entitled "Ten Years' Experience with the Swedish Select Oat," by Mr. Mark Alfred Carleton, Cerealist in Charge of Grain Investigations, and to recommend that it be published as Bulletin No. 182 of the series of this Bureau.

Twelve years or more ago, while considerable attention was paid to the oat crop in this country, there was no definite idea of the adaptation of varieties to different portions of the United States and there was great need of varieties that would give much better results in certain localities than were obtained by those then grown. About that time several different kinds of wheat, oats, barley, and other cereals were introduced into this country, particularly from Russia. Among these was the Swedish Select oat, obtained by the writer of the accompanying paper while acting as Agricultural Explorer for this Bureau. This soon proved to be admirably adapted to the northern portion of the United States.

This paper discusses the many experiments and observations made concerning this oat at several of the experiment stations and on numerous farms during the past ten years.

Respectfully,

G. H. Powell,
Acting Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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B. P. I.—566.

TEN YEARS' EXPERIENCE WITH THE SWEDISH SELECT OAT.

INTRODUCTION.

In the region between the Great Lakes and the Rocky Mountains one of the best-known varieties of oat at present is the Swedish Select. The annual production of this variety in the area mentioned is already at least 50,000,000 bushels, and in certain localities it has for some time entirely replaced all other kinds. It is the most popular oat in Wisconsin and adjacent districts, and the acreage sown each year has increased rapidly. Yet up to 1899 this oat was quite unknown in North America.

The Swedish Select oat was introduced into the United States by the writer in the spring of 1899 in time for planting that season. It was obtained, along with other cereals, while making an exploration of the cold and semiarid regions of Russia and western Siberia in 1898–99 in search of cereals adapted to corresponding conditions in this country. At the same time two other oat varieties were obtained, one of which, the Tobolsk, is of much value, but the Swedish Select is proving to be by far the best of the three in nearly every respect. It originated in Sweden as a pedigree variety developed by selection many years ago and was afterwards grown in Finland and in St. Petersburg Province, Russia. Under the severe weather conditions of these localities it became well acclimated for a cold and dry climate.

CHARACTERISTICS.

The Swedish Select variety is a large-grained white oat, with a spreading top or panicle. (See Pl. I.) The distinguishing marks are a blunt, plump kernel, with, usually, dark, slightly twisted awns and a heavy weight per bushel. It is a very prolific variety, which quality, together with the size and weight of the kernel, is no doubt the result of previous selection. The usual weight per bushel is 34 to 36 pounds, while in Montana a weight of 44 to 46 pounds is not rare. In order, therefore, to appreciate its real superiority over other varieties in yield per acre, comparison must be made on the basis of bushels

by weight instead of measured bushels. It also grows to a considerable height and produces much straw, its chief fault being a tendency toward overproduction of straw when grown on rich or low land. The roots are large and vigorous, giving the plants hardiness in cold or dry seasons. This quality was probably developed during the period of acclimation in northern Russia. Plate II shows a sample of the Swedish Select oat in comparison with two other introduced oats, Sixty-Day and North Finnish Black.

RESULTS OF TRIALS IN THIS COUNTRY.

Only 20 bushels of seed of the Swedish Select oat were obtained in the original introduction.[a] One other importation of 160 bushels was made through Mr. E. A. Bessey in 1901.[b] However, a large percentage of the present production has descended from the 20 bushels received in 1899.

In another publication of this Department[c] the following statement by the writer is made at the close of a description of this oat:

> In this country it will be suitable for cultivation in all the extreme Northern States, from New York to Washington, and in southern Alaska.

With the exception that northern New England might have been included, no statement could be more completely and accurately confirmed by present results than this one has been after ten years of experience. The results of a long series of trials show that this variety is sharply limited in its adaptation to just the region mentioned and that it is not only much superior to other kinds previously grown in that region but is just as much inferior to other kinds in adaptation to other regions. It is just as worthless for Texas and Tennessee as it is superior for Wisconsin and Montana.

The whole series of trials of the Swedish Select oat in the United States and the accompanying results have been extremely interesting. No other introduced oat has been so thoroughly and widely tested.[d]

This oat was grown on the experimental plats of the Agricultural Academy at Moscow, Russia, and was considered by Professor Williams, of that institution, to be an excellent variety for the North.

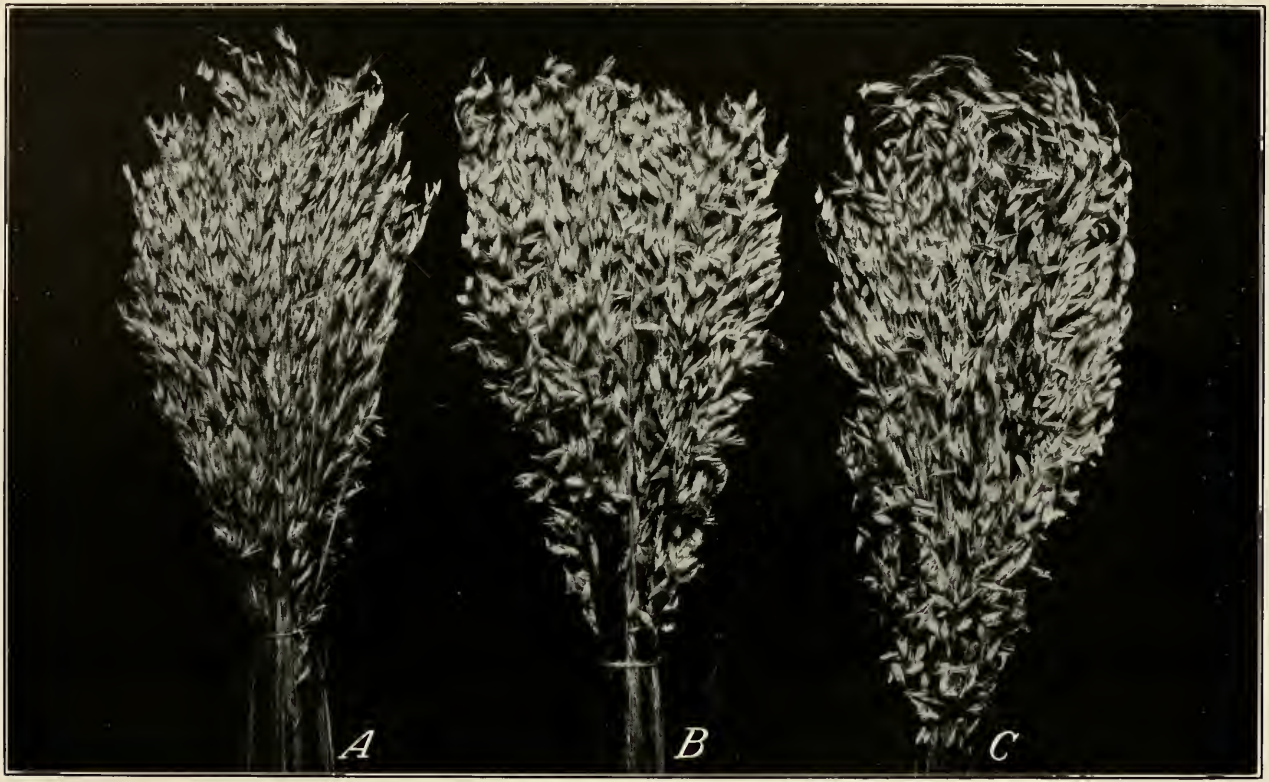
---

[a] Inventory No. 4, Division of Botany, U. S. Dept. of Agriculture, 1899, p. 3 (S. P. I. No. 2788), and Inventory No. 7, same series, 1900, p. 13 (S. P. I. No. 2788).

[b] Bulletin 66, Bureau of Plant Industry, U. S. Dept. of Agriculture, p. 276 (S. P. I. No. 9422).

[c] See "Russian Cereals Adapted for Cultivation in the United States," Bulletin 23, Division of Botany, U. S. Dept. of Agriculture, 1900, p. 21.

[d] It may be of interest, however, to state that another variety, the Sixty-Day, also from Russia, stands second in the attention it is receiving and promises to become fully as popular as the Swedish Select, although it is adapted to conditions largely just the opposite of those required by the latter oat.



THREE VARIETIES OF OATS INTRODUCED BY THE UNITED STATES DEPARTMENT OF AGRICULTURE: *A*, SIXTY-DAY; *B*, SWEDISH SELECT; *C*, NORTH FINNISH BLACK.

TRIALS BY EXPERIMENT STATIONS.

A large part of the seed of the first introduction was placed immediately with the agricultural experiment stations in the Northern States and planted in the spring of 1899. From this time forward the most extensive trials have been made at the experiment stations in Wisconsin, North Dakota, and Montana. A report of these trials will be given. In Wisconsin and North Dakota the experiments have for some time constituted a part of the regular series conducted in cooperation with this Bureau.

Wisconsin.

The results obtained by the Wisconsin Agricultural Experiment Station have been exceedingly interesting. Only 6 pounds of seed were sent to the station, and this quantity was sown on a tenth-acre plat. In the words of Prof. R. A. Moore, agronomist—[a]

> The results were so favorable that an effort was put forth to improve them by selection and careful grading of the seed for each season's crop. In all comparisons with selected varieties of oats the Swedish were equal to the best in point of yield and had several desirable characteristics superior to other varieties.

Concerning the good qualities of this variety, Professor Moore states as follows:[b]

> The Swedish Select oats (Wisconsin No. 4) seem especially adapted for high, well-drained land, and the best-known returns are from clay-loam soils. The great root development is one of the characteristics of the Swedish oats, which enables the plant to resist drought better than any other variety tested. The straw is coarse and is noted for its stiffness and power to withstand lodging. The Swedish oats lodged for the first time during the four years' test on the experimental farm the past season, this being due to the severe storm of July.

On the experiment station farm such good results were obtained in 1899 and 1900 that 7½ acres were sown in 1901, with the view of increasing the quantity of seed for distribution throughout the State. This crop made 306 bushels, a yield of 40.8 bushels per acre, in spite of the serious drought of that season. This drought, though it appears to have been particularly severe at Madison, where this good crop of Swedish Select oats was grown, was general throughout the State and, in fact, throughout the Northwest. The average yield of oats for the State was thereby reduced to less than 30 bushels per acre. There is shown, therefore, in this comparison a striking exhibition of the drought-resisting quality of the Swedish Select.

In the mean time there was organized the Wisconsin Agricultural Experiment Association, composed of people connected with the Wisconsin College of Agriculture, which association has become extremely effective in improving the crops of the State. Seed of

[a] Third Annual Report, Wisconsin Agricultural Experiment Association, p. 9.

[b] First Annual Report, Wisconsin Agricultural Experiment Association, p. 16.

the Swedish Select oat was sold to members of this association, and in 1902 forty-one members grew this oat in thirty-three different counties of the State. The average yield per acre from all these trials was 53 bushels, while the average yield of ordinary oats for the State was 40 bushels. No doubt a part of this difference in yield should be credited to the better methods of cultivation that would likely be practiced by these men, but it is probable that the larger percentage of increase was due to the variety employed. In 1903, 1904, and 1907 certain members of the association grew other varieties in comparison with the Swedish Select, with results here tabulated as follows:

1903.

Number of members reporting	100
Number of acres sown	538¾
Number of bushels harvested	23,705
Average number of bushels per acre of Swedish Select	44
Average number of bushels per acre of other varieties	37.5

1904.

Number of members reporting	30
Number of acres sown	352
Number of bushels harvested	18,300
Average number of bushels per acre of Swedish Select	45
Average number of bushels per acre of other varieties	40

1907.

Number of members reporting	96
Number sowing on fall-plowed land	64
Number sowing on spring-plowed land	32
Number sowing with a drill	44
Number sowing with a seeder	46
Number treating for prevention of smut	25
Number of cases where oats were smutted	17
Number of cases where oats rusted badly	61
Average number of bushels per acre of Swedish Select	27.9
Average number of bushels per acre of other varieties	24.3

Seed has been sold by members of the experiment association to other farmers of the State, until the Swedish Select oat has become very widely distributed. Professor Moore estimates that 150,000 bushels were grown in 1903, 4,000,000 bushels in 1904, and in 1905 8,000,000 bushels by at least 10,000 farmers. In 1906 about 12,000,000 bushels were produced, and in 1907 at least 20,000,000 bushels, though the season was very unfavorable. In 1908 no less than 30,000,000 bushels were harvested, or over two-fifths of the entire oat crop of the State. These estimates refer only to the crop descended from the original 6 pounds of seed sent to the experiment station. There is a considerable production in Wisconsin descended from other seed and referred to in another place. About three-fourths of the members of the Wisconsin Agricultural Experiment Association were growing the Swedish Select oat in 1908.

The results of a 10-year yield test of the Swedish Select oat in comparison with that of a number of other good varieties at the Wisconsin Agricultural Experiment Station are summarized below in bushels per acre, the average yield for the State being given also for further comparison:

TABLE I.— *Yield to the acre of the Swedish Select oat compared with that of other varieties grown at the Wisconsin Agricultural Experiment Station and throughout the State from 1899 to 1908, inclusive.*

Year.	Swedish Select.	Highest yield of any other variety.	Average of all other varieties.	Average yield of oats in Wisconsin.
	Bushels.	*Bushels.*	*Bushels.*	*Bushels.*
1899	50.6	65.0	49.4	36.0
1900	64.5	79.2	49.4	32.0
1901	38.1	46.8	30.2	29.1
1902	69.2	61.3	46.1	39.9
1903	72.0	72.5	59.0	32.8
1904	62.0	64.0	50.3	35.0
1905	50.0	66.8	43.4	39.0
1906	39.0	78.1	32.6	37.4
1907	12.5	33.7	17.5	22.0
1908	50.0	63.6	45.0	31.1
Average	50.8	63.1	42.3	33.4

Table I shows that the yield per acre of the Swedish Select oat as an average for 10 years is 50.8 bushels and is 8.5 bushels greater than the average yield of all other varieties tested during this time. An average of the highest yield reached by any other variety during the period is 63.1 bushels. This statement must not be misunderstood. The highest yield was not made by the same variety each year. The Swedish Select made the greatest average yield for the 10-year period. With reference to the yield of the Swedish Select oat in 1907, Professor Moore comments as follows:

> Our test plots were located in a hollow, and the heavy rains during the summer partially flooded some of the ground, and the oats were badly lodged and affected with rust to such an extent that the crop was almost a failure. A member of our experiment association, who lives near the university farm, has been carrying on tests with these (Swedish Select) oats for several years under our direction. I almost think it would be fair to use his figures in this report as he has been carrying on his work in accordance with my directions for several years. His report on 18 acres this year with the Swedish Select oats is 33 bushels to the acre.

The seven varieties yielding the highest per acre for the period 1899–1903 are as follows:

	Bushels.
Swedish Select	58.8
Big Four	56.3
Silver Mine	55.6
Early Gothland	54.8
Lincoln	53.6
Wisconsin Wonder	53.5
Siberian	53.0

The figures for the Swedish Select and the Siberian varieties are for the full 5-year period. The other varieties, except the Wisconsin Wonder, were sown first in 1900, and the average yields are therefore for 4 years only, while the Wisconsin Wonder was grown only in the 3 years from 1901 to 1903. The same varieties made the highest yields for the 7-year period from 1899 to 1905, but in the following order:

	Bushels.
Swedish Select	58.1
Wisconsin Wonder	56.1
Big Four	55.3
Siberian	54.9
Early Gothland	53.5
Lincoln	53.3
Silver Mine	50.9

The Swedish Select is the only one of the seven varieties that was grown every year of this period. The Siberian, Early Gothland, and Silver Mine were grown for 6 years, and the Wisconsin Wonder, Big Four, and Lincoln for 5 years. The average yield per acre of the Swedish Select oat for 7 years is 2 bushels greater than that of the Wisconsin Wonder, standing next highest, though from fifteen to thirty-five good varieties were compared during this time, while during 8 years it averaged 3.3 bushels per acre more than the Siberian, which yielded next highest for that period.

Such figures as the foregoing do not, however, give an accurate idea of the yields, as all varieties are not always grown the same years. By substituting Tobolsk for Lincoln we have seven kinds, some or all of which have been grown every year of certain periods. For example, the seven were grown each of the 6 years from 1901 to 1904, 1906, and 1907, with average yields per acre as follows:

	Bushels.
Swedish Select	59.5
Wisconsin Wonder	47.3
Siberian	44.1
Early Gothland	42.5
Big Four	41.6
Silver Mine	40.8
Tobolsk	36.1

Six of these seven varieties were each grown every year of the 7-year period from 1900 to 1904, 1906, and 1907, and another series of six was grown every year of the 7-year period from 1901 to 1904 and from 1906 to 1908, with yields as follows:

Period, 1900–1904, 1906, and 1907.

	Bushels.
Swedish Select	60.2
Big Four	46.3
Siberian	45.1
Silver Mine	45.0
Early Gothland	43.6
Tobolsk	38.7

Period, 1901–1904 and 1906–1908.

	Bushels.
Swedish Select	58.2
Wisconsin Wonder	46.0
Early Gothland	43.1
Big Four	42.4
Silver Mine	42.2
Tobolsk	36.8

Five of these seven varieties were grown every year of an 8-year period, 1900–1904 and 1906–1908, with the following average acre yields:

	Bushels.
Swedish Select	58.9
Big Four	46.7
Silver Mine	45.7
Early Gothland	44.0
Tobolsk	39.2

Three varieties were grown every year of the 9-year period from 1900 to 1908, with yields as follows:

	Bushels.
Swedish Select	57.9
Silver Mine	44.9
Early Gothland	43.3

The Swedish Select is the only variety grown during the entire 10-year period from 1899 to 1908, giving an average acre yield of 50.8 bushels, as already mentioned. (See Pl. III.)

This summary of the tests at the Wisconsin Agricultural Experiment Station, in which many good varieties were employed, indicates a complete victory for the Swedish Select oat. To give an average yield during 9 years of 13 bushels more than the Silver Mine, and during 8 years of 12.2 bushels more than the Big Four, which the Swedish Select has done, is an indication of exceptional merit, as these two oats are considered among the best in the North-Central States. The Wisconsin Wonder stands high in one of the 7-year periods and is apparently a good oat.

The Sixty-Day oat was grown each year of the last 4 years, 1905–1908, and during these years gave an average yield of 59.1 bushels, considerably larger than that of the Swedish Select for the same period. This period, however, includes particularly unfavorable years for the latter, compared with other sorts. During an 8-year period the Swedish Select oat gave an average yield almost equal to that of the Sixty-Day for the 4 years from 1905 to 1908.

North Dakota.

A valuable characteristic of the Swedish Select oat is its hardiness in seasons of drought and cold and its ability to produce well on high, poor land. On the other hand, under very favorable conditions for oat production it is likely to prove inferior to other good varieties.

This fact is well illustrated in the results obtained at the North Dakota Agricultural Experiment Station at Fargo. This experiment station is located in the Red River Valley, a region of low elevation, having a rich, black soil and a good average rainfall. In recent years the rainfall has been considerably above the average, finally resulting in 1905 in actual inundations of portions of the valley, including the site of the experiment station. Accordingly, no comparison of yields of oats can be given for 1905. The loss of seed by fire prevented the sowing of the Swedish Select variety in 1901. For the remaining years from 1899 to 1908 the yield per acre of the Swedish Select, compared with other varieties, is as follows:

TABLE II.— *Yield to the acre of the Swedish Select oat compared with that of other varieties grown at the North Dakota Agricultural Experiment Station and throughout the State from 1899 to 1908, except 1901 and 1905.*

Year.	Yield of Swedish Select.	Highest yield of any other variety.	Average yield of all other varieties.	Average yield of oats in North Dakota.
	Bushels.	*Bushels.*	*Bushels.*	*Bushels.*
1899	75.4	81.1	70.7	30.0
1900	23.0	45.7	29.1	10.3
1902	30.8	72.2	40.7	38.4
1903	68.2	77.3	62.8	27.4
1904	54.6	75.4	57.8	37.4
1906	48.1	55.6	46.6	32.5
1907	58.7	78.0	58.1	24.5
1908	67.0	95.2	79.8	23.4
Average	53.2	72.6	55.7	28.0

It will be observed that here the Swedish Select compares unfavorably with other varieties, its yield per acre being less than the average for all others in the years 1900, 1902, 1904, and 1908, and its average for the 8 years less by 2½ bushels than the average for all other varieties for that period. It remains, however, pretty nearly an average variety in yield for that region, and is superior to many others in size and weight of kernel. As might be supposed, it has done much better in higher and drier portions of the State westward. Prof. J. H. Shepperd, collaborator in these investigations, writes as follows:

> The Swedish Select oat has not proven a very good variety under local conditions. It does far better on our lighter and drier soil.

At the branch experiment station at Edgeley, N. Dak., in 1903 and 1904 this variety gave good results, making a yield per acre considerably greater than the average of all other varieties. (See fig. 1.)

MONTANA.

At the Montana Agricultural Experiment Station, at Bozeman, the conditions for oat cultivation are even more favorable ordinarily than at Fargo, N. Dak. Here, also, in a 5-year trial the Swedish Select oat gave yields inferior to those of a number of other varieties. In

FIELD OF SWEDISH SELECT OATS ON THE EXPERIMENT STATION FARM AT MADISON, WIS., IN 1906.

(From a photograph furnished by Prof. R. A. Moore.)

addition to the low-lying rich soil and excellent climate the oat plats had the advantage of irrigation. Other trials by farmers in other parts of the State were made under conditions of "dry farming" without irrigation. Results are available only for the period from 1900 to 1905, inclusive, and through some oversight the Swedish Select variety was not sown at the experiment station in 1902. This happened, too, to be a year of enormous yields, one variety, the Wide Awake, yielding 172.5 bushels per acre. For the remaining years

FIG. 1.—Field of Swedish Select oats in shock, at Edgeley, N. Dak., in 1904.

in this period from 1900 to 1905 the yield of the Swedish Select, compared with five other varieties, was as follows:

TABLE III.—*Yield to the acre of the Swedish Select oat compared with that of five other varieties grown at the Montana Agricultural Experiment Station during 1900 and 1901 and from 1903 to 1905.*

Variety.	1900.	1901.	1903.	1904.	1905.	Average.	Weight per bushel.	Period of growth.
	Bush.	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bushels.*	*Pounds.*	*Days.*
Progress	93.2	92.4	127.5	137.4	112.5	112.6	41.6	118.0
White Danish	99.5	92.4	114.4	135.2	138.8	116.1	41.1	118.0
Wide Awake	79.6	94.3	120.0	141.7	115.6	110.2	41.9	117.0
Scotch	79.6	95.2	97.5	153.4	112.5	107.6	41.5	116.0
Swedish Select	93.2	100.2	99.4	133.4	108.8	107.0	44.1	111.5
Bland's White	95.6	87.7	113.4	113.1	112.5	104.5	40.6	122.0

The Swedish Select oat stands fifth in the list in yield. These varieties only were grown in 1905. For the years 1900, 1901, 1903, and 1904 the following other varieties made an average yield greater than that of the Swedish Select, while several fell below it:

	Bushels.
Mogheda	109.8
American White	109.2
American Beauty	107.9
Archangel	106.9

It will be noted in Table III that the Swedish Select oat stands much above the others in weight per bushel. It is also four days earlier than any other variety. Only one variety out of fifteen, the

Badger Queen (not grown in 1905), weighed more than the Swedish Select, the average weight of the former for four years being 44.5 pounds per bushel.

South Dakota.

Next to Wisconsin, more attention has been given to the Swedish Select oat at the South Dakota Agricultural Experiment Station, at Brookings,[a] than at any other point. Here this oat has been grown throughout the 10-year period from 1899 to 1908, but in 1902 no results were reported because of the damage by wind, and in 1903 all varieties were entirely destroyed by hail. Therefore, actual results are available for only 8 years out of the 10.

During the period mentioned, 1899–1908, many varieties of oats were grown, a number of them having just been introduced by the writer from Russia and other foreign countries. In the following table is given the yield per acre obtained with some of the best sorts, only two of which, the Swedish Select and the Tobolsk, were grown each of the eight years.

TABLE IV.— *Yield to the acre of the Swedish Select oat compared with that of other varieties grown at the South Dakota Agricultural Experiment Station from 1899 to 1901 and from 1904 to 1908.*

Variety.	1899.	1900.	1901.	1904.	1905.	1906.	1907.	1908.	Average.	Number of years grown.
	Bush.	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bushels.*	
Swedish Select	41.65	22.7	59.0	70.0	45.3	61.6	24.1	25.0	43.67	8
Tobolsk	35.50	24.3	57.0	55.6	40.6	47.5	5.0	21.8	35.91	8
Sixty-Day	.....	.....	65.0	69.6	80.0	61.6	24.4	59.2	59.96	6
Lincoln, No. 151	.....	.....	.....	50.7	24.3	42.2	14.1	17.6	29.78	5
White Schoenen, No. 153	.....	.....	.....	46.8	20.6	19.4	.....	8.4	23 8	4
Bavarian, No. 150	.....	.....	.....	46.8	30.2	32.7	.....	13.4	30.77	4
Banner, No. 160	.....	.....	.....	54.7	35.2	42.7	8.1	2.5	28.64	5
American Triumph, No. 162	.....	.....	.....	52.7	30.5	45.5	10.9	4.3	28.78	5
American Beauty, No. 163	.....	.....	.....	55.6	28.7	43.8	10.3	5.0	28.68	5
North Finnish Black	.....	.....	.....	65.0	35.7	40.8	5.0	20.6	33.42	5
Holstein Prolific, No. 158	.....	.....	.....	55.6	22.8	44.4	11.9	5.4	28.02	5
Wide Awake, No. 154	.....	.....	.....	51.7	24.1	35.0	11.9	12.5	27.04	5
Abyssinian, No. 155	.....	.....	.....	54.7	25.6	37.2	14.4	16.2	29.62	5
Columbus, No. 156	.....	.....	.....	58.6	31.9	42.8	17.8	15.0	33.22	5
Golden Beauty, No. 159	.....	.....	.....	56.6	27.5	42.4	13.8	6.2	29.3	5
Belyak, No. 10624	.....	.....	.....	28.0	37.5	42.8	9.1	26.8	28.84	5

It is seen that the Swedish Select variety yielded better than any other oat except the Sixty-Day, which gave a much better average for the years it was grown, 1901–1908. During these same years the Swedish Select average was 47.5 bushels, while 59.96 bushels was the

[a] All the experiments were cooperative between this Bureau and the state experiment station and were undertaken with Prof. E. C. Chilcott (now of this Bureau) in charge of the department of agronomy at the state station and were continued afterwards while his former assistant, Mr. J. S. Cole, was in charge of the same department. Early in 1908 Prof. C. Willis was elected to this position, and beginning with the season of 1909 all cooperative experiments with the Office of Grain Investigations have been concentrated at Highmore, S. Dak., with Mr. Manley Champlin, special agent of this Bureau, in immediate charge.

Sixty-Day average. The latter is already to a large extent replacing the former in eastern sections of the State. Until recently the Swedish Select has been by far the most popular oat and is still largely employed in the drier districts. It is an attractive oat, because of the size and weight of its kernel and its usual freedom from discoloration. The Tobolsk and the North Finnish Black, standing third and fourth in rank, respectively, are also northern varieties adapted to cool, dry seasons and high plains. (See Pl. II.)

Through the medium of the state experiment stations a considerable distribution of seed of the Swedish Select oat was made to farmers in South Dakota and North Dakota. Concerning this distribution in South Dakota, Mr. J. S. Cole wrote as follows: [a]

> It was distributed in this State by the state experiment station in 1901. In 1902 a more extensive distribution was made, and every year since several hundred bushels have been sold to farmers by the station. In the western part of the State it has made a good crop in years when the common varieties were a total failure, but in the eastern and southeastern portions of the State in years of excessive moisture it is likely to grow too rank and to be damaged by rust. It is no more subject to damage in this way, however, than are all common varieties of oats.

At the branch experiment station at Highmore, S. Dak., the Swedish Select oat was grown during the period from 1903 to 1909, inclusive.[b] Here the conditions are usually severe for oat growing, and this variety gave good results compared with others, as is shown in the following table:

TABLE V.— *Yield to the acre of the Swedish Select oat compared with that of other varieties grown at the branch experiment station at Highmore, S. Dak., from 1903 to 1909, inclusive.*

Variety.	1903.	1904.	1905.	1906.	1907.	1908.	1909.	Average for 4 years (1906–1909).	Average for 5 years (1905–1909).	Average for 7 years (1903–1909).
	Bush.	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*	*Bush.*
Swedish Select	38.1	54.4	55.0	65.0	30.8	32.9	36.6	41.3	44.1	44.7
Sixty-Day	24.1	41.3	64.1	*43.3	31.5	47.5	28.8	37.8	43.1	40.2
Kherson	.....	.....	.....	69.7	28.7	45.8	21.9	41.5	.....	.....
Red Algerian	.....	.....	60.3	49.1	21.8	32.8	23.4	31.8	37.5	.....
Belyak	.....	.....	52.5	55.6	26.5	21.3	22.8	31.6	35.7	.....
Golden Beauty	.....	.....	.....	60.3	26.5	27.5	17.2	32.9	.....	.....
American Beauty	.....	.....	.....	47.8	35.3	25.3	20.3	32.2	.....	.....
American Triumph	.....	.....	.....	49.4	31.5	26.3	20.3	31.9	.....	.....
Columbus	.....	.....	.....	52.5	25.0	28.1	16.3	30.5	.....	.....
Lincoln	.....	.....	.....	45.6	30.6	29.7	15.6	30.4	.....	.....
Danish	.....	.....	.....	46.3	26.8	30.3	15.0	29.6	.....	.....
Canadian	.....	.....	.....	52.2	23.4	30.3	12.5	29.6	.....	.....
Holstein Prolific	.....	.....	.....	48.8	26.2	22.5	17.8	28.8	.....	.....
Abyssinian	.....	.....	.....	50.9	25.3	25.0	12.8	28.5	.....	.....
Wide Awake	.....	.....	.....	42.5	24.6	28.9	10.6	26.7	.....	.....
White Tartar	.....	.....	.....	44.7	26.2	25.0	4.7	25.2	.....	.....

* This yield of the Sixty-Day oat is not comparable with any of the others for that year, as it was grown after sorghum, while all the others were grown under better conditions. This is proved by the fact that the Swedish Select was duplicated on the sorghum ground and made there only 42.8 bushels per acre. However, using this figure the 7-year average, 41.5 bushels, thus resulting for the Swedish Select is still somewhat larger than that for the Sixty-Day.

[a] Bulletin 96, South Dakota Agricultural Experiment Station, March, 1906, p. 54.

[b] The tabulations in this bulletin usually do not go further than the year 1908, but there are so few years' results at Highmore, S. Dak., that it seems necessary to include here the year 1909.

Taking an average of all trials in each case, the Swedish Select variety gave the best yield, though the Kherson yielded a trifle better in the 4-year average, 1906–1909. The yield of the Swedish Select at Highmore in 1903 was not quite as good as the average oat yield throughout the State (38.6 bushels), because of severe drought in that district. Highmore is considerably west of the one hundredth meridian, where it is ordinarily very dry for oats. On the other hand, in 1905 (a wet season) and 1908 the Sixty-Day exceeded the Swedish Select in yields. With reference to the crop of 1903, Prof. E. C. Chilcott wrote as follows:

> It is worthy of note that at the driest time the Swedish Select oat appeared to be the most drought-resistant grain on the farm, with the Minnesota No. 6 Manchuria barley a close second. This appearance was borne out by the yields at harvest time.

Washington.

The Swedish Select oat was grown on the Washington Agricultural Experiment Station farm at Pullman during three seasons. In 1903 it made 55 bushels per acre. In 1904 it yielded 86 bushels, in comparison with 82.5 bushels as the highest for any other variety and an average of 61.3 bushels for all other kinds. In 1905 it yielded 53 bushels, the same as the average for all others, while it was exceeded by one variety, the Sixty-Day, which yielded 84 bushels. The average yields for the State during these years were 47.9 bushels in 1903; 44.9 bushels in 1904; and 50 bushels in 1905. The results reported by farmers from other portions of the State where the climate is drier were much more to the credit of the Swedish Select.

Colorado.

In 1900 the Swedish Select oat yielded 18 bushels per acre at the branch experiment station at Cheyenne Wells, Colo., where, at that time, it was hardly expected that any cereal crop would produce anything. The average yield of this variety at the Colorado Agricultural Experiment Station, at Fort Collins, for the years from 1905 to 1907 was 88.4 bushels, the average of all other varieties being 86.8 bushels for the same period.

Iowa.

As already mentioned, the Swedish Select oat is adapted particularly to the Northern States. Iowa may be considered as a transition area between the northern and central districts (see fig. 2). As might be expected, therefore, this oat does not compare quite so well with other varieties in that State as farther north, but nevertheless ranks rather high in acre yields. In the several years' experiments conducted at Ames by the Iowa Agricultural Experiment Station, some results of which were published by Prof. M. L. Bowman in a

"Seed Oat Special," it was found to stand third in yield among sixteen good varieties as an average of four years' trials, 1905–1908.

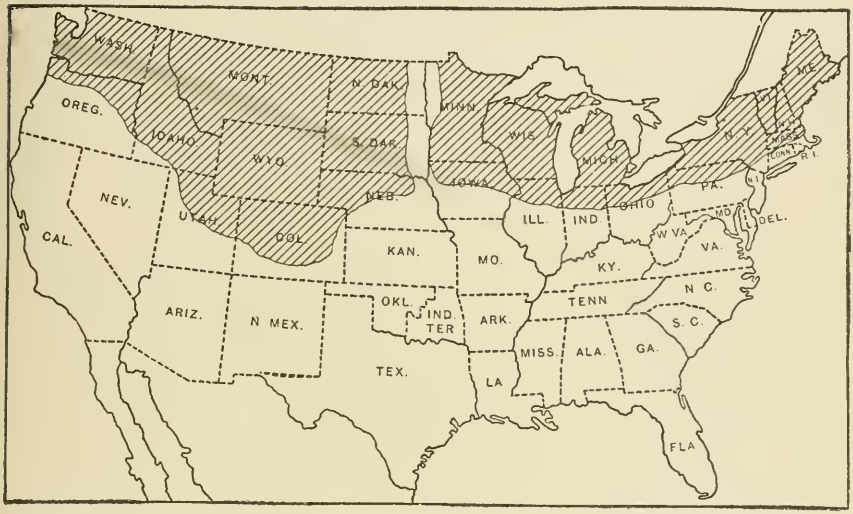


FIG. 2.—Map of the United States, the shaded portion showing the region to which the Swedish Select oat is adapted.

The following is a tabular statement of the average date of ripening, acre yield, and weight per bushel of the sixteen varieties:

TABLE VI.—*Average date of ripening, acre yield, and weight per bushel of the Swedish Select oat compared with those of fifteen other varieties grown at the Iowa Agricultural Experiment Station from 1905 to 1908, inclusive.*

Variety.	Average date of ripening.	Average yield per acre.	Average weight per bushel.
		Bushels.	*Pounds.*
Kherson	July 15	60.2	30.00
Silver Mine	July 23	56.0	27.00
Swedish Select	July 24	50.5	29.50
Sixty-Day	July 15	48.7	29.75
Minnesota, No. 25	July 24	47.6	25.25
National	July 25	47.4	28.00
White Alaska	July 14	47.0	30.75
Irish Victor	July 24	46.9	25.50
White Russian	July 30	46.3	26.50
Minnesota, No. 6	July 24	45.7	27.00
Joanette	July 26	45.3	27.75
Siberian	July 25	44.5	25.75
Early Champion	July 14	44.4	29.50
Tartar King	July 22	40.1	27.25
White Tartar	July 30	37.4	28.75
Danish	July 25	35.2	24.00

Table VI shows that only two varieties, the Kherson and the Silver Mine, exceed the Swedish Select in acre yields, and only three, the White Alaska, the Kherson, and the Sixty-Day, exceed it in weight per bushel. It may be considered, therefore, as one of the best varieties for Iowa, but not absolutely the best.

Alaska.

Under the direction of Prof. C. C. Georgeson, Special Agent in charge of the Alaska Agricultural Experiment Stations, the Swedish Select oat has been tested at one or more points in Alaska in competition with other varieties during the entire period from 1900 to 1908, except the season of 1901. In nearly all cases it either partially or fully matured, though in three instances it appears to have failed completely—at Kenai in 1903, at Sitka in 1904, and at Rampart in 1905. In two of these instances all other varieties also failed.

The weather conditions at Copper Center, though south of Rampart, are more severe than at the latter place, and cereals have usually done better at Rampart. Nevertheless, the Swedish Select oat at Copper Center was cut for seed in 1904 and gave a "good average crop," the plants being "well filled." The plants matured also in 1905 and partially matured in 1906 and 1907. The North Finnish Black, another variety introduced by this Department, is the only one that has been constantly more successful than the Swedish Select.

The specimen of the Swedish Select oat shown in Plate I was grown at Sitka in 1903.

Miscellaneous.

In some other States entirely outside of the northern oat district, such as Indiana and Ohio, the Swedish Select stands still farther removed from the top in yielding capacity in comparison with other kinds, according to results at the experiment stations, but even in those States gives results usually considerably better than the average.

TRIALS BY FARMERS.

While the tests of any crops made by farmers are not likely to be so accurate as a rule as those made at experiment stations, nevertheless more satisfactory information may often be obtained from such tests because of their greater number and the fact that they represent such a variety of conditions of soil and climate. The system of securing, filing, and summarizing reports devised in the Office of Grain Investigations and used in cooperation with the Office of Seed and Plant Introduction and Distribution has made it possible to obtain a great amount of interesting information concerning this new oat variety.

It may be of value to the reader to give extracts from some of the most important reports on the Swedish Select oat received from farmers.

Washington.

Mr. Gilbert Engbritson, of Edison, Skagit County, Wash., 80 miles north of Seattle, wrote as follows on September 15, 1904:

I beg to make a second report to your Department on the results of the second crop of the 2 pecks of No. 9422 Swedish Select oats mailed to my address February 16, 1903.

The 2 pecks planted in 1903 produced the seed for planting 7 acres in 1904, which were thrashed on the 12th instant, yielding 1,050 bushels, averaging 150 bushels per acre—a remarkable yield of bright, heavy oats of excellent quality which has attracted the attention of the entire community.

In 1906 Mr. Engbritson harvested 7,987 bushels, yielding 126 bushels per acre.

Mr. Anton Lehnhoff, of Mount Vernon, Wash., bought seed from Mr. Engbritson and in 1905 obtained a crop of 9,600 bushels, at the rate of 90 bushels per acre, while other varieties on the same farm made 75 bushels.

IDAHO.

Mr. F. W. Boehme, of Geneva, Idaho, has been a very successful cooperator in trials of different cereals received from this Department. His farm lies along the Thomas Fork of the Great Bear River, in extreme southwestern Idaho, at an elevation of 8,000 feet. On December 26, 1905, he wrote the following statement:

The Swedish Select oats yielded 1,988 pounds from 61¼ pounds of seed (corresponding to at least 65 bushels per acre), all nice, white, and heavy grain.

Clark and Haughton, of St. Anthony, Idaho, thrashed 8,000 bushels of the Swedish Select in 1905, yielding 65 bushels per acre. Other oats on similar soil and under similar treatment yielded 45 bushels per acre and weighed 5 pounds less per measured bushel.

Mr. J. D. Louis grew the Swedish Select oat 2 years at St. Anthony, Idaho. In 1906 a part of the crop was irrigated and a part not irrigated. A yield of 43½ bushels per acre was obtained on the irrigated land, compared with 35 to 40 bushels produced by other varieties. Another unirrigated field of 9 acres of the Swedish Select yielded at the rate of 70 bushels per acre, testing 40 pounds to the measured bushel.

In 1903 the average yield of the Swedish Select oat grown by several farmers at Blackfoot, Idaho, was 60 bushels per acre, as reported by Prof. H. T. French, of the Idaho Agricultural Experiment Station.

COLORADO.

Mr. C. H. Morgan, of Norwood, Colo., wrote as follows on December 27, 1905:

A very fine early oat and of good weight, 45 pounds to the measured bushel. The 2 bushels you sent me weighed only 36 pounds to the bushel; therefore, I gained 9 pounds per bushel the first year.

Mr. Morgan obtained 60 bushels per acre, while other oats made 30 bushels. In 1906 he harvested 32 bushels on one-fourth acre which weighed 45 pounds per bushel, while other varieties yielded 40 bushels per acre.

Mr. T. A. Wright grew this oat two years at Greenwood, Colo. In 1906 he obtained one bushel of oats from a seeding of 6½ quarts, and in 1907 obtained 15 bushels from one-half acre, weighing 35 pounds to the bushel. He treated his oats thoroughly for smut prevention both seasons.

Mrs. S. B. Walker, of Sedalia, Colo., grew the Swedish Select oat two years, 1906 and 1907, beginning with a very small quantity of seed. In 1907 the total number of bushels thrashed was 270, and the yield per acre 45 bushels. The highest yield made by any other variety was 30 bushels—the Colorado White. Mrs. Walker writes as follows:

There is no irrigation whatever on the place, and I am endeavoring to bring about strictly dry-farming cultivation, most of the so-called dry farming in the vicinity being simply the raising of crops without water without any regard to previous cultivation and preparation of land, and in almost every instance no regard is paid to the dry mulch.

At Lansing, in eastern Colorado, Mr. A. S. Kester grew the Swedish Select oat in 1903, obtaining a very small yield per acre, but explained it as follows:

This was the only oat thrashed in this vicinity. We had no rain all summer. The season is considered the driest for the past 17 years with the exception of 1894.

Of the crop of 1904 Mr. Kester writes the following:

Bushels thrashed, 68; yield per acre, 14 bushels. The oats did not come up till the first week in May. It was very dry here in early spring and after the middle of June.

Mr. J. A. Riedesel, of Idalia, Colo., began growing the Swedish Select variety in 1903 and finally, after two partial failures, obtained 300 bushels in 1905, that is, 30 bushels per acre, other varieties yielding 25 bushels.

MONTANA.

Mr. C. H. Austin, of Cascade, Mont., obtained 62 bushels per acre in 1902, when other kinds of oats yielded from 30 to 50 bushels. He writes as follows:

These oats had no irrigation, nor were they on extremely low land. We treated them for smut with formalin and had no trace of smut.

Mr. W. W. Cook, of Chinook, Mont., reports as follows for 1903:

Bushels thrashed, 800; yield per acre, 50 bushels, weighing 48 pounds per bushel. These are the finest oats I ever saw. I sent a sample to Bozeman the other day that weighed over 50 pounds per measured bushel.

At the same place, the same season, Mr. Rudolph Hermes thrashed 900 bushels, yielding 64 bushels per acre.

Mr. T. L. Black, of Whitehall, Mont., obtained 80 bushels per acre in 1904, weighing from 42 to 45 pounds per bushel. His remarks concerning the variety are as follows:

This oat has proved to be extra early for me, and I consider it of great value in localities where water runs short for a second irrigation. The water was applied June 20. I also find that 1¼ bushels of seed per acre give better results when water is only available for one irrigation. Should be sown from April 1 to 10 when the above-mentioned conditions prevail.

Mr. J. J. Patterson, of Truly, Mont., obtained 90 bushels per acre in 1904 and reports a weight of 52 pounds per measured bushel.

At Bozeman, Mont., Mr. Jacob Carolus obtained 1,600 bushels of the Swedish Select oat on high land without irrigation, the yield being 40 bushels per acre.

MICHIGAN.

Mr. Marvin Babbitt, of Merson, Mich., reports as follows concerning his crop of 1903:

Yield per acre, 48 bushels; quality of grain, excellent; average yield of other kinds in the same locality, about 30 bushels. The Swedish Select is decidedly the best grown in this locality. It is very plump and seems to possess all the properties an oat should have.

Mr. B. F. Beckwith, of St. Clair, Mich., obtained 80 bushels per acre in 1905, when other oats in the locality yielded only 30 bushels. He writes as follows:

As I sowed the sample in 1904 I think it was rather a remarkable yield, considering the average yield of oats in this vicinity. If, when it becomes acclimated, it does half as well it will be remarkable.

In 1906 the yield per acre was 40 bushels, while other varieties on the same farm made 20 bushels. In 1908 occurred the greatest drought for many years. Even that season the Swedish Select yielded 40 bushels per acre.

Mr. James S. Bailey, of East Paris, Mich., at the end of four years' trial writes the following:

I think these are the best oats that I have raised, and I shall sow mostly the Swedish Select this next year.

In 1906 Mr. Bailey's crop was 193 bushels, a yield at the rate of 37 bushels per acre.

Mr. R. D. Morrison, of Merle Beach, Mich., grew the Swedish Select oat during the years from 1906 to 1909, getting an average acre yield of 32.6 bushels. He writes concerning the 1907 crop as follows:

I raised these oats in the same field as I did some Big Four oats and sowed them (the former) 2 weeks later, but they were ripe about the same time.

In 1908 the yield per acre was 35 bushels, while an adjoining field of another variety made 20 bushels per acre.

SOUTH DAKOTA.

Mr. H. C. Warner, of Forestburg, S. Dak., found the Swedish Select to be the best variety out of fifty-four under trial on his farm. In 1905 it yielded 75 bushels per acre, while other varieties made 50 bushels.

This oat was grown by Mr. G. A. Grant at Sherman, S. Dak., during 1906, 1907, and 1908. In the second year he obtained a crop of 913 bushels, averaging 40 bushels per acre. In 1908 the acre yield was the same and the total production 2,453 bushels. The only other variety grown on the same farm was the Sixty-Day, also introduced by this Department, which yielded 40 bushels per acre.

Mr. J. E. Behnke, of Beresford, S. Dak., grew the Swedish Select oat 7 years, 1903 to 1909, but no report is at hand of his 1906 crop. For the other 6 years his average yield per acre was 40.5 bushels, the separate yields being for 1903, 30 bushels; 1904, 55 bushels; 1905, 48 bushels; 1907, 50 bushels; 1908, 25 bushels; and 1909, 35 bushels. Yields of other varieties for certain years were as follows: 1903, 28 bushels; 1904, 41 bushels; 1905, 35 bushels; and 1908, 20 bushels.

Prof. J. H. Shepard, of Brookings, S. Dak., in addition to his official experience with introduced grains obtained through this Department, has taken much interest in a private way in trials on his own land of some of the best varieties. He states his experience with the Swedish Select as follows:

I sowed some on corn ground, some on manured land, and some on very rich ground. My findings are as follows: Remember the season (1905) was excessively wet. After barley and after oats I got a good stand; the oats did not go down and the berries were plump and heavy. The same is true after wheat.

On rich ground the oats lodged some in patches, but they all filled. On heavily manured land they went down in patches and they filled well, except where the lodged places occurred. On corn ground they lodged more, but not enough to prevent filling in the lodged places. On no kind of ground did they all go down, but in patches only. I believe that had the season been dry I would have had no lodged oats on any of these places and that the quality of the oats would have been all that could be desired. Naturally enough, the higher the ground the better the oats were during the past wet season. During dry seasons they might be sown on low land.

The record of yields this year (1906) was somewhat lower than last, owing to my experimenting under different conditions and also to the fact that a slight hailstorm ruined many berries when they were just coming into milk. My yield this year was 65 bushels per acre, last year 75 bushels, while under the best conditions on our experimental grounds the yield rose to 84 bushels per acre. But the most remarkable thing to my mind is that on my old land, which had been systematically robbed by 25 years of wheating, the best yield of oats I ever could get was 40 bushels of White Russian oats, and I never equaled that figure with any other kind, and I tried all I could get. The first year the Swedish Select jumped immediately up to 75 bushels, while the station has shown that this is by no means the limit. I sowed but 2 bushels and 1 peck per acre, as they are heavy stoolers, but believe that heavier seeding will increase the yield.

Moreover, the analyses of these oats, as made in my laboratories, show them to be exceptionally rich in protein. It is for these reasons that we consider them to be the best all-around oats for the Dakotas. They mature in about 108 days.

New York.

An interesting 6-year trial of the Swedish Select oat was made by Mr. S. J. Smith at Manchester, N. Y., beginning in 1903. His yields per acre were 84 bushels in 1903, 80½ bushels in 1904, 70 bushels in 1905, 75 bushels in 1907, and 60 bushels in 1908, or an average for these five years of 73.9 bushels. No report is received for the year 1906. The average yield of other varieties on the same and adjoining farms for the years from 1903 to 1905 was 60 bushels, and the average yield for the State of New York for the period from 1903 to 1908 was 32.6 bushels. Mr. Smith comments on his results as follows:

(1903.) A month of very hot, dry weather retarded a good start. One marked feature of the oat is its uniform berry.

(1904.) Our men thought more seed sown would have increased the crop to 90 bushels per acre (2 bushels per acre were sown). Potatoes were grown on the land the previous year. The soil was fairly fertile.

(1905.) The oats were grown on land that had not been clovered or fertilized for 10 years, and wet weather made a lumpy seed bed. On another farm this oat outyielded two other kinds 20 bushels per acre.

(1907.) Have discontinued growing the Sixty-Day oat. It is too light and the color is not satisfactory. The Swedish Select forwarded to us by you in 1903 is an ideal oat in every way. Can not grow enough to supply our seed trade.

(1908.) It has produced fine crops and the very best farmers have continued growing this variety. It is well adapted to clay soil. Last year our sales were about 4,000 bushels, and we could have sold many carloads at good prices if we had had the supply.

Wisconsin.

As already mentioned, the most extensive series of tests of the Swedish Select oat by farmers was made in Wisconsin. These tests were rendered all the more thorough and accurate through the important part taken by members of the Wisconsin Agricultural Experiment Association. There are now in this office reports on this oat for both 1904 and 1905 from more than two hundred cooperators in Wisconsin. A number of these have sent reports for other years also. Very brief extracts are here reproduced from some of the most instructive of these reports.

Mr. A. D. Larson, of Waupaca, Wis.:

(1904.) The Swedish Select proves to be very well adapted to our soil and climate. It is by far the best yielder and of good quality. Yield per acre, 57 bushels. American Banner, 40 bushels.

(1905.) The soil on which I sowed the oats has been cropped continuously for 12 years without any fertilizer or clover seeding, yet the Swedish Select did very well. Yield per acre, 28 bushels. Average yield of other varieties, 20 bushels.

Mr. Joseph Reich, of East Gibson, Wis.:

(1904.) The oats ripened earlier than other oats of this vicinity, which had some smut and were more affected by the rust in general. Yield per acre, 86 bushels. Quality of grain, extra good. Average yield per acre of other kinds in the same locality, 50 to 60 bushels.

(1905.) I must say that this oat has a tendency to lodge in our locality. I would have thrashed at least 75 bushels if none had lodged, but I had to cut about half of it for hay. It ripens a week or 10 days earlier than our other varieties. Yield per acre, 55 bushels. Quality of grain, extra good. Average yield of other kinds in same locality, 35 to 40 bushels.

Mr. H. W. Kent, of Rusk, Wis.:

(1904.) The oats were cut a little green because of the rust and lodging. This variety does better than other varieties grown here. Yield per acre, 45 bushels. Quality of grain, average. Average yield per acre of other kinds in same locality, 40 bushels.

(1905.) This oat does better on light soil than on heavy. Yield per acre, 40 bushels. Quality of grain, good. Average yield of other kinds in the same locality, 30 bushels.

Mr. J. W. Stevenson, of Rice Lake, Wis.:

(1904.) I consider it a very good variety for this locality, being a good yielder and standing up well. Yield per acre, 50 bushels. Average yield of other kinds, 45 bushels.

(1905.) The Swedish Select for the last 3 years has yielded about 10 bushels more per acre than other varieties I have grown, and I think it is superior for feeding purposes. Yield of other varieties in same locality, 25 bushels.

Mr. A. C. Hagastad, of Etrick, Wis.:

(1904.) The ground was a mixed clover and timothy sod, and one of the lowest and worst fields we have for lodging. When the crop was 4 to 6 inches high we had about one week of cold, rainy weather, which set it back for a long time. It ripened several days ahead of our Siberian oat. It is a heavy yielder, the kernels are large and plump. Will sow all Swedish Select next year. Yield per acre, 70 bushels. Quality of grain, No. 1. Average yield of other kinds in same locality, 60 bushels.

(1905.) The straw is heavy and stiff, so will not lodge easily on rich soil. On lighter soil the straw is not so large but heads out good. Yield per acre, 66 bushels. Quality of grain, No. 1. Average yield of other kinds, 50 to 60 bushels.

Mr. Clarence Jordalen, of Stoughton, Wis.:

(1904.) Am very well pleased with the Swedish Select oat. I like it because it is a greater yielder than the other oats I have raised. It has a very stiff straw and will not lodge very quickly. Yield per acre, 60 bushels. Quality of grain, fairly good. Average yield of other kinds in same locality, 35 bushels.

(1905.) The variety seems to be adapted to this part of the country, for all who try it meet with success and grow no other kinds. Yield per acre, 62 bushels. Quality of grain, exceedingly good; plump and heavy. Average yield of other varieties in same locality, 30 bushels.

Mr. John E. Charley, of Ellsworth, Wis.:

(1904.) I am sorry to say that this oat is not liked here. I had it two years, but did not sell one bit of it for seed. The straw is too coarse and the hull is too thick. We have had the Lincoln and Silver Mine.

Mr. P. J. Bonzelet, of Eden, Wis.:

(1905.) This is the best oat, all things considered, that I have ever seen. Yield per acre, 60 bushels. Quality of grain, good. Average yield of other varieties, 35 to 40 bushels.

Mr. Edward Martin, jr., of De Pere, Wis.:

(1904.) This oat is of the finest quality I have ever seen. It will weigh about 40 pounds to the bushel. When I seeded last spring it averaged 108 pounds to the sack.

Mr. F. H. Williams, of Whitewater, Wis.:

(1905.) I am not at all pleased with the Swedish Select oat. Have tried it 2 years with about the same result. It does not yield good, crinkles down as soon as it begins to ripen, and has a very thick hull. One of my neighbors had 20 acres on good prairie soil that only yielded about 30 bushels per acre. Another got a yield of 23 bushels per acre. Yield per acre, 25 bushels. Quality of grain, good; very thick hull. Yield per acre of American Banner, same locality, 40 bushels.

Mr. J. W. Raven, of Bloomer, Wis.:

(1904.) Those that see the oats want seed. It is the best we have ever raised. A common grain sack holds 105 to 120 pounds. Will have seed grown from 100 acres to sell next year. Yield per acre, 40 bushels. Quality of grain, No. 1. Average yield of other varieties, 35 bushels.

Mr. John Patterson, of Cumberland, Wis.:

(1904.) I have grown this oat for 2 years and will say that while the yield is very good the quality is extra good and it ripens from 10 days to 2 weeks before any other variety and about 4 weeks before the side oats, which is the latest kind we have here. All the Swedish Select I grew last year I sold for seed, and what I have grown this year will be sold for seed. Yield per acre, 68 bushels. Average yield of other varieties on same farm, 55 bushels.

Mr. H. S. Pomroy, of Edgerton, Wis.:

(1904.) I did not keep a record of this variety, but found it not nearly as good as common white oats grown next to it under the same conditions. I shall not try it next season.

Mr. C. A. Peterson, of Cambridge, Wis.:

(1904.) The Swedish Select is superior to other varieties in even stand, earliness, heavy kernel, and trueness to type. Yield per acre, 58 bushels. Quality good. Average yield of other varieties, 26 to 30 bushels.

Mr. H. R. Moldenhauer, of Lebanon, Wis.:

(1904.) The Swedish Select is the best oat ever raised in this country. All other varieties had very much rust, this oat not enough to mention. The berry is plump, and the yield is more than double that of other crops. Yield per acre, 75 bushels. Quality very good. Average yield of other varieties, 30 bushels, and poor at that.

Mr. A. J. Moe, of Midway, Wis.:

(1904.) The variety is a fair yielder, stands up well, weighs heavy, and ripens about 2 weeks earlier than other kinds. Yield per acre, 40 bushels. Quality, fine and plump. Average yield of other kinds, 25 to 30 bushels.

Mr. Reuben Holmgreen, of Black River Falls, Wis.:

(1904.) My Swedish Select was the best of three kinds. Yield per acre, 70 bushels. Quality of grain, No. 1. Average yield of other varieties in same locality, 40 bushels.

Mr. W. S. Hood, jr., of Franksville, Wis.:

(1904.) People who saw the Swedish Select claim it was as nice an oat as they had ever seen and wished me to save seed for them. The kernel has a large meat and thin shuck. Yield per acre, 50 bushels. Quality of grain good. Yield per acre of Silver Mine oat, 40 bushels.

Mr. H. D. Griswold, of West Salem, Wis.:

(1904.) Other oats adjoining the Swedish Select on the same farm yielded 48 bushels per acre, while the latter yielded 61 bushels. Many fields of other varieties yielded only 30 bushels.

Mr. G. R. Downer, of Appleton, Wis.:

(1904.) This is the third year I have grown this oat, and I like it better than any I have ever tried. Yield per acre, 63 bushels. Quality good. Average yield of other varieties, 50 bushels.

Mr. John Dougan, of Beaver Dam, Wis.:

(1904.) The only fault I can find with this variety is that the hulls are rather thick and tough. Yield per acre, 50 bushels. Average yield of other varieties, about 40 bushels.

Mr. C. R. Blodgett, of Marshfield, Wis.:

(1904.) The best oat I have ever used in this locality, and I try to get the best. Yield per acre, 96 bushels. Quality good. Average yield of other varieties, 65 bushels.

Mr. J. W. Kaiser, of Foxlake, Wis.:

(1904.) I was very much pleased with this variety. I had 15 acres this year and harvested 700 bushels of the best oats in this part of the country. Other varieties averaged from 15 to 35 bushels per acre.

Some conflict may be noted in these reports in respect to the lodging of the Swedish Select oat. This may be because of local differences in soil conditions or "lay of the land," or more often, perhaps, because of different previous experiences with other varieties. This oat is known to lodge badly on low rich ground. At the same time, some other varieties may lodge worse. There is also a difference in opinion as to the thickness of the hull. This variety is probably not far from the average in this respect, so the hull may appear thick or thin to the grower, depending on the varieties he has formerly grown.

MISCELLANEOUS.

Mr. J. M. Maher, of Fremont, Nebr., writes as follows concerning his crop of 1905:

It was drilled in on April 25 on cornstalk ground that was disked over twice and not plowed, and was harvested July 20, and was stacked and thrashed October 18. It yielded 680 bushels on 10 acres, or 68 bushels per acre. It was well matured when I cut it, but it never broke down like the other kinds of oats I had alongside of it.

At Odebolt, Iowa, in 1904, the yields of ordinary oats were 40 to 45 bushels per acre, while the Swedish Select yielded from 50 to 60 bushels. Mr. J. A. Cranston, of that place, writes as follows:

These oats ripened about 5 days earlier than common oats.

L. and H. Goeppinger grew the Swedish Select variety for 3 years at Boone, Iowa, and in 1906 harvested 789 bushels, making an average yield of 43 bushels per acre, compared with 36 bushels produced by other oats. This is especially good, inasmuch as in recent years there have been wet seasons in that region which are particularly unfavorable to this variety.

Mr. A. W. Edson, of Austin, Minn., writes: "In this vicinity oats had to be planted in soil too wet." Yet, in his second year's trial of the Swedish Select (1906) it yielded 52 bushels per acre, compared with 40 bushels produced by other varieties. In 1907 the yield was 23 bushels per acre, other varieties averaging 18 bushels.

At North Water Gap, Pa., Mr. Luther Michael obtained a yield of 129 bushels per acre with the Swedish Select in 1904. In his report he makes the following statement:

Quality of grain, first class. Average yield per acre of other oats in the same locality, 40 bushels. The Swedish Select made a very rapid growth from the start and ripened 10 days earlier than any other variety in this section sowed at the same time. It is the best oat I ever grew.

Mr. M. B. Smith grew the oat at Belfast, Me., in 1903, and reports as follows:

Sown broadcast and harrowed in (would have done better drilled). Yield per acre, 65 to 70 bushels. Quality of grain, best I ever saw. Yield per acre of other kinds in same locality, 45 to 50 bushels. It was said by farmers who saw it that it was stouter and of better quality than any other grain they had ever seen raised in that country.

INTERESTING INDIVIDUAL TRIAL.

The most interesting case of success with the Swedish Select oat is that of the trial by Mr. David Jones, of Brandon, Wis. In the early spring of 1899 his son, Prof. L. R. Jones, of the University of Vermont, during a brief visit to the United States Department of Agriculture, obtained 36 kernels of this oat from an exhibition sample and sent them to Mr. David Jones. These were planted that same spring, and we have the following account from Prof. L. R. Jones of the behavior of the variety from that time forward:

Each seed was planted by itself, 6 inches apart. Thirty-three of the seeds grew, making a strong stand and yielding 1¾ pounds of grain. The next year, 1900, all of the 1¾ pounds was sown in drills, but no further attention was given it. Unfortunately, the grain was invaded and trampled down in midsummer, and so did not have a chance to develop a full crop. The yield was approximately 1 bushel. The third year, 1901, this bushel was sown broadcast on one-half acre and no special care given to it. The yield was 40 bushels of grain by measure, weighing 40 pounds per measured bushel, producing, therefore, 50 bushels by weight at 32 pounds per bushel.

In 1902 about 5 bushels of this seed were given to each of three other persons. None of their crop was saved as seed and no record is available of their yields. Mr. Jones sowed about 35 bushels on 12 acres. This yielded 900 measured bushels, weighing 40 pounds per bushel, which by weight would amount to 1,125 bushels. The yield was, therefore, 93 bushels per acre by weight. All of this crop was saved for seed.

In the fifth year, 1903, about 750 bushels of Mr. David Jones's crop were used by him or sold in his immediate neighborhood for seed. The only exact available record for the season is that Mr. F. E. Jones sowed 20 bushels on 10 acres and obtained a crop of 780 bushels by measure, weighing 40 pounds per measured bushel, making, therefore, a yield by weight of 975 bushels, or at the rate of 97.5 bushels per acre. It would be a safe estimate to say that 20,000 bushels were produced from this seed in 1903.

Mr. David Jones has taken much interest in work of this kind, which has not only been of much public benefit, but has always resulted very profitably to himself because of his careful selection of seed and the manner in which the crop has been handled. He has done similar thorough work with other varieties of oats, one of which, the Sixty-Day, was also introduced by this Department.

RECENT REPORTS.

Many of the preceding reports were written several years ago. The following reports are more recent and give a good idea of present conditions in Wisconsin with respect to this oat.

Mr. H. F. Kramer, of Bloomer, Chippewa County, Wis.:

It gives me pleasure to testify to the merits of Swedish Select oats, which I have grown for the past 6 years, for they have surpassed any of the other varieties tried in this locality in appearance, weight, large, plump kernels, early maturity, and a strong straw. While attending the short course in agriculture during the winter of 1902, I saw these oats for the first time. They appeared to be so much better than any others that I determined to secure some for seed, and was one of the first to apply when Professor Moore offered them to the experiment association for trial. The plat of ground on which they were sown was a good fertile soil, and the growing oats had a thrifty and healthy appearance all summer. When ready to harvest the oats averaged about 5 feet in height. The 80 pounds of seed which I had secured yielded 56 measured bushels, or 70 by weight. The season of 1903 was an unfavorable one to the growth of oats, but they led all others that I noticed. Even this last summer of 1907, the poorest in years, the Swedish oats are ahead at least 5 bushels per acre, and in quality also. One more feature, they are practically free from smut and very easily kept so. I have tried both broadcast seeder and the drill with 2½ bushels to 3½ bushels per acre, but find that 3 bushels sown with a drill produces the best results. I have had a ready sale for all that I have grown, in fact, never had enough to fill all of the orders I receive for seed. After shipping seed to various parts of the country, both by carload and in small lots, I have yet to hear the first complaint. To sum it all up, they do well and take wherever tried.

Mr. Fred G. Stroup, of Fond du Lac, Fond du Lac County, Wis.:

The land on which the oats were sown was black prairie soil which sloped to the west with good natural drainage. The land had had corn on it the year before. From the 4 acres we thrashed 180 bushels, machine measure, or 45 bushels per acre. The other oats that we raised that year in the same field, following the same crop, yielded 52 bushels, machine measure, but were sown 2 bushels per acre, while the Swedish

Select were sown 1 bushel per acre. We consider that the Swedish Select oats did considerably the best and have grown them exclusively during the past 3 years. We have had them yield as high as 75 bushels per acre by weight. We have sold this variety quite extensively for seed to farmers living in our neighborhood, and there is not a single case where it did not do better than the other varieties. The neighboring farmers have been loud in their praise of the Swedish Select oats.

Mr. H. E. Rosenow, of Oconomowoc, Waukesha County, Wis.:

We have been growing the Swedish Select oats for the past 4 years with satisfactory results as compared with other varieties, although we have at no time had an extra heavy crop. Comparing the yield with a variety of yellow oat grown for several years past, we have found the Swedish to yield a few bushels more per acre when grown in the same field; both varieties seemed to be affected about equally with rust, and during the past 3 years the rust has no doubt lowered the yield considerably. The Swedish oats also lodged quite badly nearly every year, but all other grain also went down, and thus it can not be said that some other variety has a stiffer straw, as they all seemed to be treated alike during some of our heavy storms, but I believe if the Swedish is given a fair chance it will stand up with any other variety grown. It has a somewhat coarser straw than some smaller varieties of yellow oats grown about here, and the kernel is also larger, but in comparing the inside of the kernel it will hold its own with any variety regardless of color, as the hull is very thin, thus increasing the feeding value considerably.

The demand for pure seed from this variety has been exceptionally good during the past few years, and we have always sold all we had to offer for seed at a fair price and have not only sold to growers in the neighborhood, but have shipped a considerable quantity to other farmers, as well as carloads to seed houses. It is just as easy to grow pure seed of any variety, and there is certainly more profit and pleasure connected with it.

Mr. Charles H. Howitt, of Randolph, Dodge County, Wis.:

We have been growing the Swedish oats for the past 4 years. In the spring of 1904 I secured 1½ bushels of seed from L. L. Olds Seed Company. This was sown on three-fourths of an acre of ground alongside of our common variety. The soil was of a heavy clay nature. There was a difference to be seen all through the growing season, the Swedish being of a darker green color and seemed to make a heavier growth. About 10 days before ripening they lodged quite badly on account of a storm, and accordingly the grain that we thrashed was rather light weight. The yield was at the rate of 50 bushels per acre.

The following spring we sowed 8 acres of the Swedish and 6 acres of our common variety in separate fields on the same kind of soil and both following a crop of barley. The Swedish yielded a trifle over 50 bushels per acre and the common variety 40 bushels per acre, a difference of 10 bushels in favor of the Swedish oats. The past 2 years we have grown the Swedish oats entirely for our main crop, with very satisfactory results.

The Swedish oats are now grown quite extensively in our neighborhood, and from what I have been able to learn from those who have grown them they seem to be the best adapted to a well-drained heavy soil.

QUALITY OF THE KERNEL IN THE SWEDISH SELECT OAT.

Soon after the introduction of the Swedish Select oat, many Wisconsin farmers remarked on the quality of the kernel, mentioned the thinness of the hull, and considered it to be in several respects an improvement over other kinds. (Pl. IV.) Our own investigations

later have shown that several other varieties exceed the Swedish Select both in weight per bushel and proportion of meat to hull, but a larger number of varieties are inferior to it in these characteristics, and particularly so in the case of Wisconsin oats. Compared with the more commonly grown varieties, therefore, it remains true that this kernel stands rather high in quality in the chief oat districts of the United States.

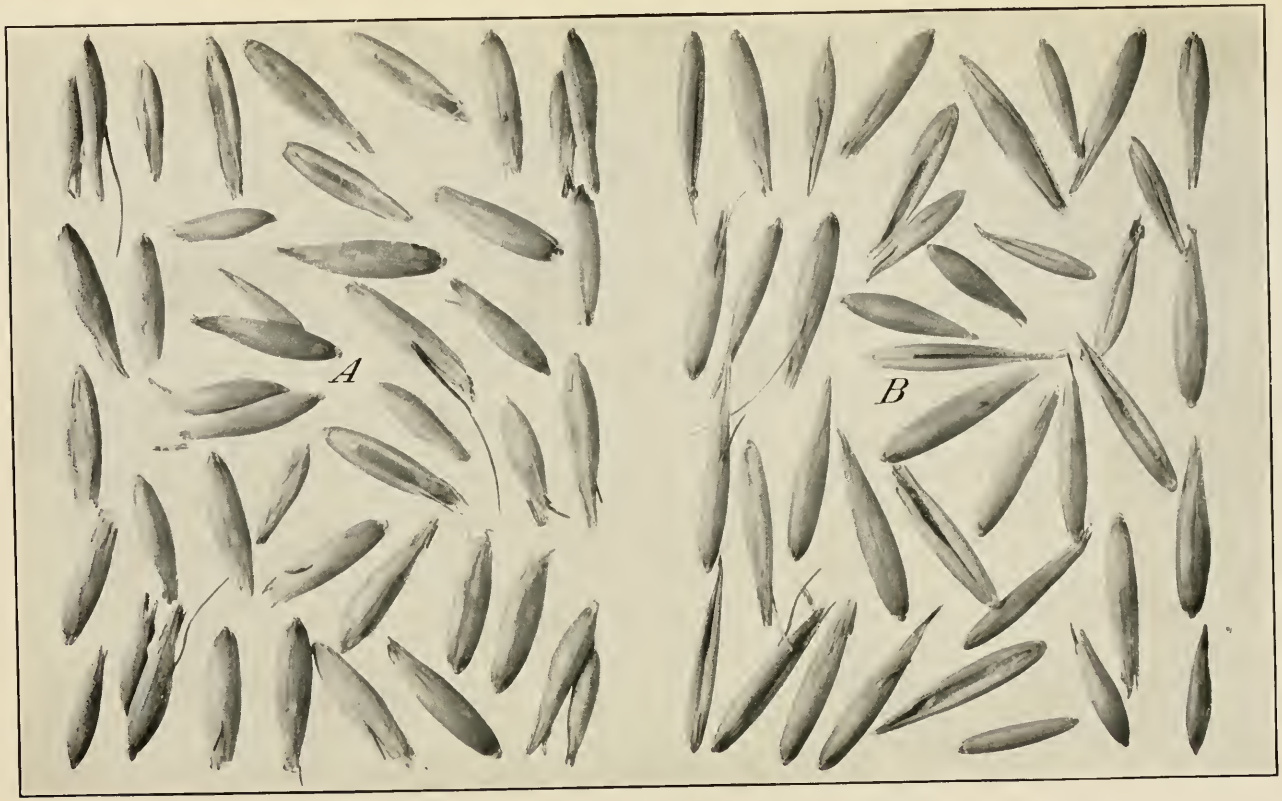
The following interesting determinations were furnished by Mr. C. W. Warburton, now in charge of oat investigations of the Bureau of Plant Industry. The weight per bushel, the weight of 1,000 kernels, and the percentage of meat in the kernel were determined in samples of a number of different oat varieties grown in Wisconsin, Kansas, North Dakota, and Montana, with results as given in the following table:

TABLE VII.—*Weight per bushel, weight of 1,000 grains, and percentage of kernel to whole grain in a number of different oat varieties grown in several States.*

WISCONSIN.

	1905.	1906.	1907.	Average.
Kherson.				
Weight per bushel (pounds)	35.50	33.75	25.25	31.50
Weight of 1,000 grains (grams)	22.19	18.75	12.68	17.87
Percentage of meat in kernel	78.07	70.08	65.65	71.27
Sixty-Day.				
Weight per bushel (pounds)	30.50	29.25	26.25	28.67
Weight of 1,000 grains (grams)	18.85	16.88	13.97	16.57
Percentage of meat in kernel	72.60	73.74	66.45	70.93
Swedish Select.				
Weight per bushel (pounds)	34.00	36.50	27.50	32.67
Weight of 1,000 grains (grams)	24.25	29.71	23.84	25.93
Percentage of meat in kernel	70.09	69.63	67.44	69.05
White Bedford.				
Weight per bushel (pounds)	35.50	.....	24.50	30.00
Weight of 1,000 grains (grams)	21.65	.....	17.70	19.67
Percentage of meat in kernel	73.42	.....	65.83	69.62
White Tartar.				
Weight per bushel (pounds)	32.50	.....	27.00	29.75
Weight of 1,000 grains (grams)	19.84	.....	19.38	19.61
Percentage of meat in kernel	69.13	.....	69.86	69.49
Belyak.				
Weight per bushel (pounds)	35.50	.....	26.00	30.75
Weight of 1,000 grains (grams)	25.98	.....	17.41	21.69
Percentage of meat in kernel	70.35	.....	67.38	68.86
Wisconsin Wonder.				
Weight per bushel (pounds)	33.50	.....	23.00	28.25
Weight of 1,000 grains (grams)	23.73	.....	17.33	20.53
Percentage of meat in kernel	70.16	.....	63.71	66.93
Golden Fleece.				
Weight per bushel (pounds)	.....	29.50	22.25	26.00
Weight of 1,000 grains (grams)	.....	19.28	15.47	17.37
Percentage of meat in kernel	.....	57.55	66.17	61.86
N. K. & Co. White.				
Weight per bushel (pounds)	.....	23.75	19.75	21.75
Weight of 1,000 grains (grams)	.....	22.78	15.74	19.26
Percentage of meat in kernel	.....	54.86	59.61	57.24

Bul. 182, Bureau of Plant Industry, U. S. Dept. of Agriculture.



KERNELS OF SWEDISH SELECT (*A*) AND LINCOLN (*B*) OATS.

(About one and one-half times natural size.)

TABLE VII.—*Weight per bushel, weight of 1,000 grains, and percentage of kernel to whole grain in a number of different oat varieties grown in several States*—Continued.

MONTANA.[a]

	1906.	1907.	Average.
Sixty-Day.			
Weight per bushel (pounds)	39.00	35.75	37.37
Weight of 1,000 grains (grams)	24.44	22.64	23.54
Percentage of meat in kernel	77.64	76.05	76.84
Swedish Select.			
Weight per bushel (pounds)	40.25	38.75	39.50
Weight of 1,000 grains (grams)	32.89	29.82	31.35
Percentage of meat in kernel	77.69	71.40	74.54
Salzer's Big Four.			
Weight per bushel (pounds)	40.25	41.00	40.62
Weight of 1,000 grains (grams)	28.54	29.06	28.80
Percentage of meat in kernel	76.30	70.75	73.52
Siberian.			
Weight per bushel (pounds)	42.00	41.25	41.62
Weight of 1,000 grains (grams)	32.99	33.86	33.42
Percentage of meat in kernel	70.99	75.46	73.22
Clydesdale.			
Weight per bushel (pounds)	40.25	41.00	40.62
Weight of 1,000 grains (grams)	31.72	30.59	31.15
Percentage of meat in kernel	75.28	69.36	72.32
Progress.			
Weight per bushel (pounds)	41.50	40.75	41.12
Weight of 1,000 grains (grams)	30.52	29.78	30.15
Percentage of meat in kernel	72.35	72.29	72.32

[a] All samples of grain from Montana contained a considerable percentage of hulled kernels; hence, the weight per bushel is somewhat higher than the grain itself justifies.

NORTH DAKOTA.

	1906.	1907.	Average.
Sixty-Day.			
Weight per bushel (pounds)	38.25	35.75	37.00
Weight of 1,000 grains (grams)	19.44	22.22	20.83
Percentage of meat in kernel	75.29	75.81	75.55
Seventyfive-Day.			
Weight per bushel (pounds)	.....	36.00	.....
Weight of 1,000 grains (grams)	.....	24.01	.....
Percentage of meat in kernel	.....	73.45	.....
Swedish Select.			
Weight per bushel (pounds)	37.50	34.00	35.75
Weight of 1,000 grains (grams)	30.14	28.84	29.49
Percentage of meat in kernel	69.49	70.78	70.23
Tartarian.			
Weight per bushel (pounds)	.....	31.00	.....
Weight of 1,000 grains (grams)	.....	23.08	.....
Percentage of meat in kernel	.....	68.15	.....
Belyak.			
Weight per bushel (pounds)	.....	31.75	.....
Weight of 1,000 grains (grams)	.....	26.48	.....
Percentage of meat in kernel	.....	67.58	.....
North Finnish Black.			
Weight per bushel (pounds)	.....	30.00	.....
Weight of 1,000 grains (grams)	.....	21.19	.....
Percentage of meat in kernel	.....	66.40	.....

KANSAS, 1907.

	Weight per bushel.	Weight of 1,000 grains.	Meat in kernel.
	Pounds.	*Grams.*	*Per cent.*
Sixty-Day	34.50	20.27	75.85
Early Champion	29.25	17.44	74.32
White Russian	27.25	20.31	72.63
Kherson	26.50	17.46	72.45
Swedish Select	38.75	32.01	72.19
Red Rustproof	27.75	25.75	70.54
Stavropol	25.25	17.33	69.92
Silver Mine	26.25	21.79	68.62
Minnesota, No. 202	25.25	19.34	67.87
Canadian	28.50	21.85	60.84

The percentage of meat in the kernel was determined by hulling 100 kernels taken at random from a fair sample, weighing the hulls and inside portions separately, and then calculating the percentage of the latter weight to the combined weight. An average of three such determinations for each sample gave the result that is set down for each variety each year.

The largest amount of data was obtained from Wisconsin material. Of the varieties examined from that State, the Swedish Select stands much the highest in weight per bushel in an average of samples from 3 years' crops, the average weight for this oat being 32.67 pounds. Only one other variety, the Kherson, reached even 31 pounds. In weight of 1,000 kernels in grams the Swedish Select also exceeds any of the others. This quality, however, is not important. In percentage of meat in the kernel this variety falls considerably below those having the highest percentages, ranking only fifth in this respect. The Kherson and the Sixty-Day are considerably higher, while the White Bedford and the White Tartar are also somewhat higher.

Average determinations of Montana samples out of two years' crops show the Swedish Select to be inferior in weight per bushel to four others in a comparison with five varieties. In weight of 1,000 kernels it stands second in rank, and, what is more important, is second also in percentage of meat in the kernel.

In the case of the North Dakota varieties there are averages of 2 years' samples in only two instances, those of the Sixty-Day and the Swedish Select, the latter exceeding the former in both weight per bushel and weight of 1,000 kernels, but falling considerably below it in percentage of meat in the kernel. For the 1907 crop only, the Swedish Select is exceeded by the Seventyfive-Day oat in both weight per bushel and percentage of meat, but exceeds the latter in weight of 1,000 kernels, and exceeds all the three remaining varieties in all these qualities.

Kansas samples were examined from only one year's crop, that of 1907. Compared with nine other kinds, the Swedish Select ranks fifth in percentage of meat, falling considerably below the Sixty-Day in this quality, but exceeds all other varieties in both weight per bushel and weight of 1,000 kernels.

A series of tests similar to the above was made by Shepperd and Churchill with a considerable number of varieties at the North Dakota Agricultural Experiment Station, samples being taken from the crops of 1904, 1905, and 1906.[a]

The results of these tests show that the Swedish Select stands considerably above the average of oat varieties in percentage of meat in

[a] Bulletin 75, North Dakota Agricultural Experiment Station, February, 1907, pp. 317–322.

the kernel, but considerably below the best in this respect, the Sixty-Day and the Tartarian being usually the best. In average weight per bushel it was good and stood rather high in weight of 1,000 kernels.

On the whole, the tests just mentioned indicate that the Swedish Select oat is usually high in weight per bushel and very high in absolute weight of kernels. At the same time, the percentage of meat in the kernel is found to be higher than might be expected, always above the average, and sometimes unusually high. The combination of these qualities therefore indicates that the feeding value from these standpoints is much above the average.

CHEMICAL ANALYSES.

For comparison, many chemical analyses of this oat and of others have been made by Dr. J. S. Chamberlain, formerly of the Bureau of Chemistry of this Department, in connection with laboratory work in cooperation with this Bureau. These analyses[a] show no extreme quality in the Swedish Select, but indicate that it is a variety of good feeding value, possessing a protein content above the average and a narrow nutritive ratio; that is, the ratio of protein to carbohydrates and fats is rather high. There is an unusually important feature of these analyses, however, in the fact that the average results with 128 samples of domestic-grown Swedish Select oats show a considerable increase in protein content over the original introduced seed. This is very gratifying, in view of the claim sometimes made that introduced crops, although an improvement at first, tend to deteriorate afterwards.

VALUE OF THE INTRODUCTION.

As previously mentioned, the Swedish Select oat has received the greatest attention in Wisconisn, though also grown to a large extent in South Dakota and Montana. It has been shown that the 10-year average yield of this oat at the Wisconsin Agricultural Experiment Station was 8½ bushels greater than the average of all other varieties. Also, calculating the averages of the highest yielding varieties for several different periods, in which all varieties were grown every year, there is a constant difference in yield of about 12 bushels per acre in favor of the Swedish Select in comparison with the next highest variety. Taking the mean of these two determinations, or, rather, reducing the latter one (for it is the most accurate), we can probably safely assume a constant average increase in yield of at least 10 bushels per acre for the Swedish Select over that of other varieties in these tests.

As all varieties were grown under the same conditions it is reason-

[a] See "The Feeding Value of Cereals," Bulletin 120, Bureau of Chemistry, U. S. Dept. of Agriculture, 1909, pp. 18–25.

able to infer that the Swedish Select oat will show the same superiority over ordinary kinds when grown throughout the State. It will therefore be interesting to calculate the possible increase in oat production in Wisconsin if this oat were grown exclusively. The average oat acreage of Wisconsin has recently been about 2,400,000 acres, and the average production about 80,300,000 bushels. The proportion of this production that is already Swedish Select is 30,000,000 bushels, or nearly three-eighths of the crop. With the same yield per acre, this portion would be grown on nearly three-eighths of the acreage, but of course it is really less. For safety in calculation we will assume it to be just three-eighths. Then there remains five-eighths of the acreage, or about 1,500,000 acres, now sown to other varieties. Ten bushels on each of these acres, or in all 15,000,000 bushels at least, would therefore be added to the present oat production of Wisconsin if Swedish Select oats were grown exclusively.

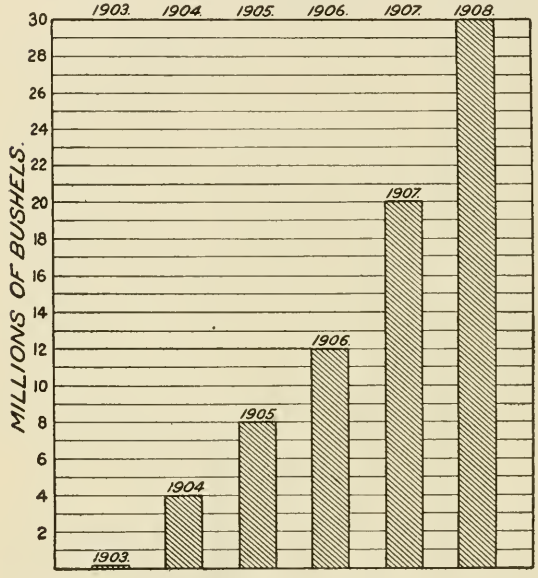


FIG. 3.—Diagram showing in millions of bushels the rapid increase in the production of Swedish Select oats in Wisconsin from 1903 to 1908.

Now, what is the actual present increase in production in Wisconsin due to the use of this oat? As stated, the present Swedish Select acreage is less than three-eighths of the total. Again, for safety in calculation we may assume it to be at this time at least one-fourth, or 600,000 acres. Ten bushels increase on each of these acres, or, 6,000,000 bushels in all, is therefore the present annual addition to the oat production of Wisconsin that can conservatively be credited to the use of the Swedish Select. The value of this increase in production at 36 cents per bushel, the average farm price December 1 for the years 1904–1908, is $2,160,000. The average farm price for 1907, 1908, and 1909, however, was 44 cents per bushel, which would increase the value to $2,640,000. Add to this the facts that the 6-million-bushel increase is reckoned up to 1908 only and that this extra production no doubt continues to be somewhat greater each year, and it is seen that the present increase in farm value

is probably not far from $3,000,000 annually, and certainly over $2,500,000, but the more conservative figures will be used.

The estimated production of the Swedish Select oat in Wisconsin ranges from 150,000 bushels in 1903 to 30,000,000 bushels in 1908. This rapid increase is shown graphically in figure 3. Figure 4 shows the average farm value of the entire oat crop of Wisconsin, that of the Swedish Select oat alone, and the increase in farm value of the entire crop due to the use of the Swedish Select variety.

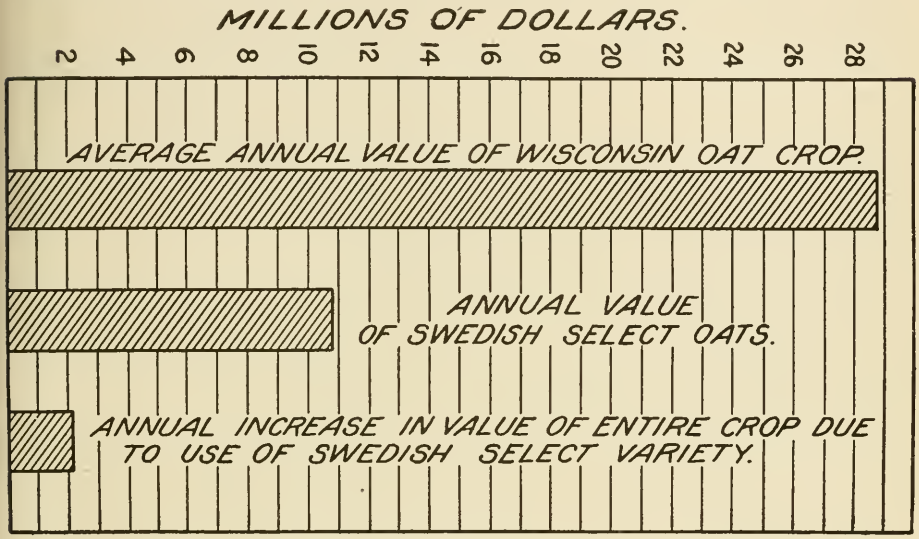


FIG. 4.—Diagram showing in millions of dollars the average farm value of the entire oat crop in Wisconsin, that of the Swedish Select oat, and the annual increase in the farm value of the entire crop due to the use of the Swedish Select variety.

Outside of the State of Wisconsin the present production of the Swedish Select oat is more difficult to estimate, but, as already stated in the introduction, the entire production in the United States is surely 50,000,000 bushels annually. Using this figure, the present farm value of the Swedish Select oat at the average farm price per bushel for the years 1904–1908 is at least $18,350,000 annually.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 183.

B. T. GALLOWAY, *Chief of Bureau.*

FIELD STUDIES OF THE CROWN-GALL OF THE GRAPE.

BY

GEORGE G. HEDGCOCK,

PATHOLOGIST, FRUIT-DISEASE INVESTIGATIONS.

ISSUED JULY 23, 1910.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1910.

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[Continued on page 3 of cover.]

A MISSION GRAPEVINE BADLY DISEASED WITH CROWN-GALL, SHOWING AN OLD DEAD CANE AND A YOUNG LIVE ONE FROM THE ROOT.

U. S. DEPARTMENT OF AGRICULTURE.
BUREAU OF PLANT INDUSTRY—BULLETIN NO. 183.
B. T. GALLOWAY, *Chief of Bureau.*

FIELD STUDIES OF THE CROWN-GALL OF THE GRAPE.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., April 11, 1910.

Sir: I have the honor to transmit herewith a paper entitled "Field Studies of the Crown-Gall of the Grape," by Dr. George Grant Hedgcock, Pathologist, Investigations in Forest Pathology.

The paper embodies the results of several years of investigation of the crown-gall of the grape in the western United States, especially of the susceptibility and immunity to the disease of a number of the most important varieties of grapes. It is found that a few varieties are resistant to the crown-gall, and that the use of the varieties Rupestris St. George and Lenoir as stocks for engrafting congenial nonresistant varieties affords a ready means of successfully overcoming the effects of the disease under soil and climatic conditions favorable to such varieties.

Studies on the congeniality of *Vitis vinifera* to resistant stock varieties, and the adaptation of varieties to soil, climatic, and other conditions, are discussed by Prof. George C. Husmann in Bulletin 172 of this Bureau.

The writer of this paper is indebted to Prof. Fabian Garcia, of the Agricultural Experiment Station of New Mexico, for hearty cooperation in obtaining information as to the extent of crown-gall in that Territory.

This paper completes the work of Doctor Hedgcock on the subject, but studies of the field end of this disease will be continued by the Office of Fruit-Disease Investigations of this Bureau.

I recommend that this paper be published as Bulletin No. 183 of the special series of this Bureau.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

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ILLUSTRATIONS.

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PLATE I. A Mission grapevine badly diseased with crown-gall, showing an old dead cane and a young live one from the root ..... Frontispiece.

II. Fig. 1.—A Muscat of Alexandria grapevine diseased with confluent root galls. Fig. 2.—A Muscat of Alexandria grapevine diseased with confluent galls on both the cane and root..... 36

III. Fig. 1.—A Flame Tokay grapevine diseased with globose root galls. Fig. 2.—A globose root gall on a Muscat of Alexandria grape seedling 36

IV. Fig. 1.—A portion of the experimental vineyard at Bernalillo, N. Mex., showing diseased Mission grapevines. Fig. 2.—A portion of the experimental vineyard at Bernalillo, N. Mex., after it had been planted with resistant grapevines 36

B. P. I.—575.

FIELD STUDIES OF THE CROWN-GALL OF THE GRAPE.

INTRODUCTION.

A disease of grapevines, under the various names of "black-knot," "crown-knot," "root-knot," "crown-gall," and "root tumors," has been known in the United States for many years. As early as 1880 it had become common in California (61)[a] and often resulted in serious injury to the vineyards. With the introduction of European vines into new localities the disease has become widespread.

During 1903 Prof. Fabian Garcia, of the New Mexico Agricultural Experiment Station, found that a disease was killing the grapevines at Bernalillo, N. Mex. The station having no plant pathologist the Bureau of Plant Industry was requested to make an investigation of the epidemic, and the task was assigned to the writer.

A preliminary examination of the vines revealed the presence of galls in large numbers on the canes and roots of many of them. Experiments were at once undertaken for the control of the disease and the cure of the diseased vines. After a thorough test of ordinary remedies with little or no results, an experiment was conducted to find varieties resistant to the disease.

Meanwhile studies were made of the cause, nature, communicability, and effect of the disease. This involved a number of species and varieties of grapes and a series of experiments in the greenhouse and gardens at St. Louis, Mo., and later at Washington, D. C.

This bulletin outlines the history of the disease and gives the results of these studies and experiments, which are of a preliminary nature, but are of great importance, especially to growers of grapes in Texas, New Mexico, Arizona, and California. Certain varieties of grapes are found to be so susceptible to crown-gall as to be unprofitable for vineyards in many localities, while others are resistant to a considerable degree and are recommended for planting. Methods for the prevention and control of the disease are outlined.

[a] The serial numbers in parentheses used in this paper refer to the bibliography which will be found on pages 31 to 33.

Prior to July 1, 1907, this investigation was conducted in the Mississippi Valley Laboratory of the Bureau of Plant Industry at St. Louis, Mo., under the supervision of Dr. Hermann von Schrenk.

For convenience, two forms of crown-gall of the grape are recognized in this bulletin. The underground or subterranean form developing at or below the surface of the ground (see Pl. III) is designated as root galls; the form appearing on the canes of the vines above the surface of the ground (see Pl. II, fig. 2) is designated as cane galls.

HISTORICAL NOTES.

It is probable that the crown-gall of the grape originated in the older countries of Europe or possibly in Asia where vines were first cultivated, but efforts to trace the disease even back to the middle ages were futile.

The first written record found in the literature examined was a reference to the form of the disease occurring on the canes of the grapevine by Fabre and Dunal (19) in 1853. This form is usually called "broussin" or "broussins" in French descriptions. According to Viala (55) it is also called, including the form on the roots, "exostoses," "exostoses fungoides," and "fongosités." The following French investigators have described and reported the disease: Cazalis (6) and Joly (32) in 1873; Du Breuil (16) in 1875; Planchon (38) and Seillan (42) in 1882; Corvo (11) in 1885; Prillieux (39) in 1888; Viala in 1887 (55), 1893 (57), and 1896 (56); Zacharewicz (63) in 1894; Ravaz (40) and Giard (25) in 1897; and Durand (18) in 1907.

In Germany, Dornfield (15) in 1859 described a form of disease called "Grind," consisting of galls or outgrowths on the canes of grapevines. This form of disease has also been known in Germany by the names "Schorf," "Raude," "Mauche," "Ausschlag," "Krebs," and "Kropf," the last name being also applied to the form of the disease appearing as galls upon the roots of vines.

Since Dornfield's time the following investigators in Germany have written concerning the disease: Köhler (33) in 1869; Goethe in 1875 (28), 1878 (26, 27), and 1882 (29); Von Thümen (58) in 1884; Beinling (2) in 1891; Frank (21) in 1895; and Sorauer in 1886 (48) and 1908 (46, 47).

In Italy, Garovaglio and Cattaneo (23) in 1879 described a disease called "rogna" on the canes and roots of the grapevine similar to the disease known in France as "broussins" and in Germany as "Grind." This was followed by publications by the following investigators: Comes in 1885 (8) and 1891 (7); Corvo (11) in 1885; Cuboni (12) in 1889; Martelli (37) in 1891; and Cavara in 1895 (4) and 1897 (5). The disease is also known in Italy under the names "malattia dei tubercoli" and "tubercoli."

In the United States in 1889 Galloway (22) under the name of "black-knot" described the form of crown-gall occurring on the canes of grapevines. This he considered the same as the "broussins" of the French, the "Krebs" or "Schorf" of the Germans, and the "malattia dei tubercoli" of the Italians. The disease on the canes or roots of grapevines has since either been reported or described in the United States by the following investigators: E. F. Smith (44) in 1894; Woodworth and Wickson in 1892 (61) and 1894 (62); Stewart and Blodgett (49) in 1899; Stewart, Rolfs, and Hall (50), and Toumey (51) in 1900; Garcia (24), Whipple (59), and Hedgcock (31) in 1906; and Lawrence (35) in 1907. Under the name "necrosis," Reddick (41) in 1909 described a gall disease of the canes of grapevines in New York which is apparently the same as the crown-gall, "broussins," "rogna," and "Grind."

In England, Cooke in 1893 (9) and 1903 (10) described a gall on the roots of grapevines which resembles the crown-gall in its gross appearance.

In Canada, Fletcher (20) in 1889 described a disease of the canes of the grapevine under the name "black-knot," which is apparently the same as the form described by Galloway (22) and Reddick (41) and the crown-gall occurring on the canes of vines of European grapes (*Vitis vinifera* L.) described in this bulletin.

In Chile, Dehors (13) in 1894 and Lataste (34) in 1896 described a tubercular or gall disease of the grape similar to the crown-gall of the roots of vines in this country.

In New South Wales, Blunno (3) in 1901 reported a cancerous disease of the grapevines which is apparently the same as the forms of the disease on the canes and roots of vines in this country and Europe.

In Cape Colony the disease is reported by letter by the entomologist, C. P. Lounsbury, with specimens on the canes of grapevines undoubtedly identical with the form of disease described on the canes of vines in this bulletin.

In the Netherlands, Van Hall (54) in 1902 described a gall disease of the grapevines, which he considered the same as the "rogna" of the Italians.

The disease has been observed by the author on the canes of grapevines in northern Mexico near Ciudad Juarez and Nogales.

DISTRIBUTION AND IMPORTANCE OF CROWN-GALL.

GEOGRAPHICAL DISTRIBUTION OF THE DISEASE.

If all the forms reported by the citations on the preceding pages are one disease, which is very probable, the crown-gall is widely distributed and probably occurs wherever European grapes are grown.

The crown-gall or a similar disease is thus reported on grapevines in Europe from Germany, France, Italy, Denmark, and England; in North America, from the United States, Canada, and Mexico; in Australia, from New South Wales; and in Africa, from Cape Colony.

In the United States the disease occurs in nearly every locality where varieties of *Vitis vinifera* are grown. It occurs on some American varieties in Canada and various portions of the United States. The author has observed the disease in localities in the following States and Territories: Washington, Oregon, California, Arizona, New Mexico, Colorado, Texas, Arkansas, Nebraska, Missouri, and Iowa.

DISTRIBUTION OF THE DISEASE ON SPECIES AND VARIETIES OF GRAPES.

In the United States, as well as in foreign countries, the varieties most susceptible to the disease belong to the species *Vitis vinifera*. There are a few exceptions to this rule, especially in the northern United States (41) and Canada (20), where varieties, hybrids or crosses, of *Vitis labrusca*, Champion, Salem, and others are attacked by the form of the disease on the canes. Varieties of *Vitis linsecomii* and *Vitis aestivalis* are occasionally diseased on both canes and roots. Varieties of *Vitis rupestris* are rarely attacked by either of the forms of the disease and appear to be nearly immune. Data will be given later in this bulletin on the resistance of individual varieties of several species.

DISTRIBUTION OF THE DISEASE ON YOUNG AND OLD VINES.

The disease has been found to a limited extent on the roots of yearling vines of *Vitis vinifera* in vineyards and nurseries in Texas, Arizona, New Mexico, California, Oregon, and Washington. It is most common on the roots and canes of older vines, increasing in extent as the vines grow older. The oldest vineyards usually contain the highest percentage of diseased vines.

IMPORTANCE OF THE DISEASE.

In Germany, France, and Italy earlier writers report whole vineyards destroyed by the crown-gall. Later writers minimize the importance of the disease. This decrease of disease is no doubt due largely to the use of American varieties of grapes and their hybrids for ingrafting with varieties of *Vitis vinifera* in the replanting of vineyards destroyed by the phylloxera. It may also be due to the gradual selection of the more resistant European varieties by growers of grapes. Our observations and experiments sustain such a conclusion, since American varieties are more resistant to

the crown-gall and a great variation of susceptibility is shown by European varieties.

In Cape Colony, as well as in the United States, certain varieties are subject to the crown-gall, such as the Muscat of Alexandria (Hanepoot). Mr. C. P. Lounsbury reports, by letter, that as much as 70 per cent was found diseased in a vineyard six or seven years old planted with Hanepoot (Muscat of Alexandria) vines. In vineyards in Texas, New Mexico, and Arizona all the vines of this variety and of the Mission variety are often diseased, and many of them are dead at the end of four years. In one vineyard at Bernalillo, N. Mex., 3,000 Mission vines died from the disease in four years from the time the vineyard was planted. The loss from the ravages of the disease is a large and important item in many localities, especially in this section, amounting to many thousands of vines.

If we consider the northern form of disease known as necrosis (41) or black-knot (22) as identical with crown-gall, the importance of the disease is greatly increased. Until it has been definitely proved that this form of disease is due to a different organism, owing to the apparent similarity of the black-knot of the Northern States and the cane-gall form of crown-gall in the Southwestern States, the writer will consider these forms of disease identical.

DESCRIPTION OF THE FORMS OF CROWN-GALL.

ROOT GALLS.

The disease is most frequently found in its earlier stages in the form of more or less spherical, fleshy galls, or outgrowths (Pl. III, fig. 2), from the roots of young plants grown from cuttings or at the point of union of scion and root in young grafted vines. These usually originate in a wound. They often become confluent (Pl. II, fig. 1).

These galls at first are white or flesh colored and can not be distinguished from callus, but they usually develop more rapidly. The surface as they grow older is more or less coarsely convoluted. They more frequently occur near the surface of the ground and often attain a diameter of 2 or 3 inches on large vines.

CANE GALLS.

The disease on old vines extends from the crown upward and attacks the older branches of the canes, often to the height of from 3 to 5 feet from the ground. Fleshy excrescences or confluent galls develop usually along lines parallel to the length of the canes (Pl. II, fig. 2). These growths are sometimes continuous for several inches or may develop in bunches. In spring the young galls resemble

wound tissue, but later in the season they often assume a dark-brown or black color due to the death and decay of the outer tissues.

OTHER MANIFESTATIONS OF THE DISEASE.

The disease manifests itself in a number of ways in addition to the formation of galls. The affected vines are stunted in their growth. The leaves are usually smaller and are often etiolated or chlorotic. The galls usually die annually, and if under ground they commonly rot away, the decay killing the adjacent tissues of the root and often killing the vine above the point of attack.

DEVELOPMENT OF THE FORMS OF CROWN-GALL.

DEVELOPMENT OF ROOT GALLS.

The subterranean form of the disease usually does not develop abundantly the first year on vines grown from cuttings. An exception must be made where cuttings are taken from diseased vines. In an experiment with cuttings selected from healthy and diseased vines of the same varieties a marked difference was noted in the relative development of the disease. The experiment was conducted as follows:

Cuttings were taken from apparently healthy and from plainly diseased Thompson Seedless, Zabalkanski, Black Malvoisie, and Mission vines from the same vineyards at Bernalillo and Mesilla Park, N. Mex. They were planted in the greenhouse in sterilized soil in sterilized pots[a] and watered with boiled water. The results of the experiment are shown in Table I.

TABLE I.—*Results of an experiment to determine the relative susceptibility to crown-gall of four varieties of grapes grown in New Mexico, cuttings being made from apparently healthy vines and from vines plainly diseased.*

Variety.	Diseased cuttings.			Healthy cuttings.		
	Number of plants in test.	Healthy plants resulting.	Diseased plants resulting.	Number of plants in test.	Healthy plants resulting.	Diseased plants resulting.
		Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
Thompson Seedless	25	80.0	20.0	33	100.0	0.0
Zabalkanski	4	50.0	50.0	7	100.0	.0
Black Malvoisie	43	60.5	39.5	43	79.0	21.0
Mission	19	68.4	31.6	19	94.7	5.3
	91	67.0	33.0	102	90.2	9.8

It will be seen from the table that the use of cuttings taken from plainly diseased plants increased the development of the crown-gall

[a] Sterilized in an autoclave for three hours at a temperature of 110° C. (230° F.).

from 9.8 to 33 per cent, or 23.2 per cent. It is also seen that where cuttings were selected from apparently healthy vines in diseased vineyards some of them (9.8 per cent) became diseased upon rooting. Similar results were obtained by cuttings planted in the soil in a vineyard.

Nearly all of the galls formed on the vines grown from cuttings in the experiment just mentioned were more or less spherical in shape and developed below the surface of the ground, often on the lower ends of the cuttings.

In structure these root galls are from the first very spongy and watery. They consist at first entirely of parenchymatous tissue. Later there develops in the interior curled and distorted masses of wood cells and vessels, and older galls occasionally become quite woody, especially where they do not die at the end of the growing season.

The gall develops in every instance, where closely observed, either from an injury to the meristem layer beneath the bark of the cuttings or from a cut surface. An outgrowth of cells first takes place directly from the meristem layer, resembling callus. This develops rapidly into a gall.

DEVELOPMENT OF CANE GALLS.

In the cane galls a similar development takes place, but it is not so rapid. Cane galls usually form along a line of injury, often from a wound made in pruning. Very frequently the bark of the canes of grapevines susceptible to frost, such as the Muscat of Alexandria, is ruptured by freezing in the spring after growth has begun. The bark is usually ruptured in longitudinal lines. From the meristem layer in these wounds there develops directly numerous rough galls which are more or less confluent. This gives rise to the form of disease (Pl. II, fig. 2) known in this country as black-knot (22) and in Europe as broussins (42), rogna (23), and Grind (15). These galls often become more or less woody in structure.

The cane galls have been observed as common, with few exceptions, only in localities where vines are subject to frost injury. Where they have been found on vines, all forms of variation have been noted from the spherical root galls of the roots and crowns of the vines to the confluent cane galls on the shoots, indicating that they are both forms of the same disease.

The cane galls usually dry up in autumn, and may break away from the canes the following season, especially when a further development of galls takes place along their margin.

DEVELOPMENT OF THE DISEASE ON SEEDLINGS.

The seedlings used in the experiments described in this bulletin, unless otherwise designated, were grown from seed sterilized in concentrated sulphuric acid for ten minutes, neutralized with a 10 per cent water solution of potassium hydroxid, and then washed in sterile water. These were planted and grown in soil sterilized in an autoclave at a temperature of 110° C. (230° F.), placed either in pots similarly sterilized or in benches constructed of new pine and cypress lumber, and washed on the surface with a 2 per cent water solution of copper sulphate.

Seedlings of the following varieties of grapes were grown under these conditions: Flame Tokay, Muscat of Alexandria, Mission, Malaga, Black Malvoisie, Concord, Delaware, Catawba, and Niagara. All such seedlings remained free from the disease except where they were wounded and inoculated either with pieces of root galls or with cultures of bacteria. The galls on small seedlings develop at a much more rapid rate than the diameter of the canes or roots of the plants on which they occur; for example, on the root of a vine with a diameter of a quarter of an inch a gall developed in two months with a diameter of an inch (Pl. III, fig. 2).

Cane galls did not develop on any of the plants in the experiments, as all inoculations were made on the vines either at or just below the surface of the soil.

DEVELOPMENT OF THE DISEASE IN VINEYARDS.

In vineyards wherever the disease is found in its worst forms the galls are developed on the roots in great numbers by the end of the third year from the time of planting the vines. Beginning about the fourth year there takes place a development of galls on the canes of some of the diseased plants, but on many vines the disease develops only below the surface of the soil.

THE EFFECT OF CROWN-GALL.

The presence of the disease on grapevines becomes apparent within a short time after they are attacked. Usually the leaves lose their healthy dark-green color and become more or less chlorotic, varying with the intensity of the disease. The growth of the canes becomes slower until they die above the point of attack, due to the cancerous effect of the disease.

The galls have a poor epidermal covering, which is constantly being ruptured during their development. This permits the evaporation of the sap of the vines. In the dry climate of the southwestern United States this loss of sap easily becomes a serious matter and quickly results in the lowering of the vitality of the diseased vines.

In New Mexico, Arizona, and western Texas the vines are usually cut back and grown by the stump system (Pl. IV, fig. 2), in order to cover the vines with soil during the winter as a protection against cold. In spite of the fact that the vines are protected, they are injured in the spring by frost after they are uncovered and severely pruned. The bark is often burst by freezing near the surface of the ground, and this enables the disease to easily gain an entrance on the canes. The vine soon dies above the point of attack (Pl. I). New shoots then develop from the canes or roots below the diseased portion, as shown in this illustration. These shoots are never so vigorous as the original ones and have a tendency to sprawl over the ground, it being a difficult matter to establish a new erect stump or vine (Pl. IV, fig. 1). After the vine dies back a couple of times it is usually worthless, although it may remain alive at the roots. This condition frequently obtains at the end of four to five years under conditions favorable to the disease. In California, Oregon, and Arizona it usually requires a longer period. A large number of vineyards in localities in California where vines suffer little from late frost were found almost free from the disease.

THE SUSCEPTIBILITY AND RESISTANCE OF SPECIES AND VARIETIES OF GRAPES TO CROWN-GALL.

Two factors apparently enter into the problem of the resistance and immunity of grapevines to the disease:

(1) The susceptibility of the species or variety to frosts, etc., in the locality where it is grown. This varies not only with the species but also with the variety grown; for example, the Concord, Catawba, Delaware, and other American varieties are perfectly hardy and usually free from the disease in sections where varieties of *Vitis vinifera* are seriously injured by freezing in winter and late frosts in the spring and become badly diseased.

(2) The variation in the chemical constituents of the sap of different varieties of grapes may enter into the problem of resistance. The sap of the vines of some of the resistant varieties is especially acid to the taste, much more so than that of some of the more susceptible varieties. This acidity may increase the resistance. Unfortunately no chemical determination has been made to fully establish this opinion, and it is offered as a working hypothesis for future investigators.

In the Southern and Western States it was found by observation that varieties of *Vitis vinifera* are less resistant than those of *Vitis labrusca* and *V. aestivalis*, although in Arkansas in the Ozark region two species became slightly diseased, one variety of which, Goethe, a hybrid of *Vitis vinifera* and *V. labrusca*, became badly diseased in a

number of instances at the age of from 10 to 12 years. Some varieties of *Vitis aestivalis*, such as Herbemont, appear to be immune to the disease.

Vines of *Vitis cordifolia* and *V. linsecomii* purchased from a nursery were found badly diseased with crown-gall, indicating a susceptibility of these species to the disease.

Vines of varieties of *Vitis rupestris* and *V. vulpina*, so far as observed, are apparently quite resistant, in fact almost immune to the disease; for example, Rupestris St. George and Rupestris Martin.

THE SUSCEPTIBILITY OF VARIETIES OF EUROPEAN GRAPES.

All the data collected from experiments and observation indicate that there is a great range of variation in susceptibility of the varieties of any given species to the disease.

Of the varieties diseased to the greatest extent in any given locality it was observed in general that those most easily injured by late spring frosts are most susceptible to the disease. There are probably some exceptions to this rule, since the disease is able to gain an entrance into the tissues of vines through wounds without the action of frost.

The varieties of *Vitis vinifera* that were found in the experiments most susceptible to the disease were the Mission from California, Muscat of Alexandria, Flame Tokay, Rose of Peru, and Malaga varieties. There are no doubt others not included in the experiments that are equally susceptible.

At Bernalillo, N. Mex., an experimental vineyard for the study of the disease has been conducted since 1903. The vineyard originally contained vines of the Mission variety from California, badly diseased with crown-gall at the age of 4 years (Pl. I). These vines were first treated in various ways in an attempt to control the crown-gall, but without success. The diseased vines were then replaced chiefly with other varieties of *Vitis vinifera* in an effort to obtain resistant vines. A number of the best varieties of commercial wine and table grapes grown on their own roots, purchased in California, were set in the holes from which the diseased Mission grapes had been removed (Pl. IV, fig. 1). This put the new vines to an exact and extreme test, since each vine was planted in infected soil.

The vines of some varieties became badly diseased in two years and were replaced at the end of the second year with more resistant varieties. The following table presents the result of the experiment to July 1, 1909:

TABLE II.—*Percentage of diseased vines of each variety of grapes grown in the experimental vineyard at Bernalillo, N. Mex., in infected soil.*

Variety.	Number of vines grown.	Age.	Proportion of diseased plants resulting.	Growth of plants.
		Years.	*Per cent.*	
Rupestris St. George	300	3	1.0	Very good.
Feher Szagos	500	5	5.0	Do.
Sweetwater	400	3	5.4	Do.
Golden Chasselas	500	3	7.2	Uneven.
Seedless Sultana	300	5	8.1	Good.
Carignane	100	3	9.0	Do.
Grenache	200	3	10.0	Do.
Gros Colman	50	5	11.0	Do.
Mataro	300	3	12.0	Do.
Sauvignon Vert	200	3	13.3	Uneven.
Black Malvoisie	500	3	14.0	Good.
Burger	200	3	17.0	Do.
Lenoir	500	5	18.7	Very good.
Zinfandel	200	5	22.3	Good.
Purple Damascus	100	5	24.0	Uneven.
Thompson Seedless	100	5	24.6	Do.
Riesling	300	5	36.0	Good.
Burgundy	300	3	46.0	Uneven.
Malaga	100	5	52.0	Do.
Rose of Peru	50	3	64.0	Do.
Mission (New Mexico)	1,000	5	75.0	Do.
Flame Tokay	300	3	70.0	Do.
Muscat of Alexandria	650	3	72.5	Do.
Mission (California)	300	5	95.0	Do.

It will be seen from the table that the varieties showing the least disease are headed by the hybrid Rupestris St. George, which shows a resistance of 99 per cent. The vines of this variety that were diseased showed only traces of the crown-gall and no effects whatever. Other promising varieties are Feher Szagos, Sweetwater, Seedless Sultana, Carignane, Grenache, Gros Colman, Mataro, Black Malvoisie, Burger, and Lenoir. The affected vines of these varieties were, as a rule, but slightly diseased, and have shown a good growth.

The most diseased vines, viz, Mission, Muscat of Alexandria, Flame Tokay, Rose of Peru, Malaga, Burgundy, Thompson Seedless, and Purple Damascus, will not prove profitable in infected soil in conditions similar to those at Bernalillo.

The land upon which these vines were grown is a sandy, alluvial deposit of the Rio Grande River, underlain chiefly by sand and gravel. It was examined by Mr. W. W. Mackie, of the Bureau of Soils, October 22, 1906, and samples were taken for a test for alkali. In a report dated November 12, 1906, to the Chief of the Bureau of Soils, Mr. Mackie reported alkali in injurious amount in only three very small areas of the vineyard. This shows that in the greater portion of the vineyard there was not sufficient alkali in the soil to hasten the death of the vines, as is often the case in the arid regions.

The experiment was also not complicated by the presence of phylloxera. The vines were carefully examined each year, but no evidence of their presence was found.

Data collected from nearly a hundred vineyards in six States in the southwestern and western United States yield similar conclusions as to the susceptibility of varieties. The most diseased varieties observed among those commonly grown in vineyards, taken in order from the highest percentage of disease to the lowest, were as follows: Muscat of Alexandria, Malaga, Mission, Flame Tokay, Black Malvoisie, and Zinfandel. Of varieties grown to a much less extent the following, arranged in the same order as before, were also found badly diseased: Black Morocco, Purple Damascus, Early Madelaine, Black Prince, Trousseau, Zabalkanski, Verdel, and Burgundy.

Among the vines commonly grown, those observed to be least affected by the disease, in the order of their immunity, were the following: Seedless Sultana, Sweetwater, Lenoir, Thompson Seedless, Feher Szagos, and Burger.

Of the vines grown to a lesser extent, the least diseased, taken in the same order as before, were Carignane, Gros Colman, Mataro, Black Prince, Black Portugal, and Grenache.

Of stocks for grafting, the Rupestris St. George, Rupestris Martin, and Herbemont appear to be almost immune.

THE RESISTANCE OF VARIETIES OF AMERICAN GRAPES.

The writer conducted no vineyard experiments with varieties of American grapes, but secured data from a number of vineyards in which the disease had appeared. Through the courtesy of Prof. W. G. Vincenheller, director of the Arkansas Agricultural Experiment Station, notes were taken on a vineyard at the station in which there was a large number of varieties of American vines and their hybrids. These vines were about 12 years old, and the disease had been observed in the vineyard for a number of years. The vines were planted on gently sloping land, consisting of an upland clay loam. The diseased vines were chiefly on the upper side of the vineyard, in such a position that the water ran from them to the vines lower down. The cultivation of the plat was made at right angles to the line of drainage, thus tending to spread the germs of disease throughout the plat by cultivation and drainage.

In the table and lists which follow the results of the experiment are given. The names of species of grapes here and elsewhere in this bulletin are in accordance with those used in Bailey's "Cyclopedia of American Horticulture." The data on the ancestry of each variety were furnished by Dr. George C. Husmann, Pomologist in charge of Viticultural Investigations of this Bureau.

TABLE III.—*Percentage of diseased vines of each variety of grapes grown in the experimental vineyard at Fayetteville, Ark., in infected soil.*

Variety.	Variety or hybrid of—	Proportion of diseased plants resulting.
		Per cent.
Mary Ann	*Vitis labrusca*	80
Telegraph	do	40
Perkins	do	20
Dracut Amber	do	20
Duchess	*Vitis labrusca* ×	40
Black Pearl	*Vitis vulpina*	40
Faith	*Vitis vulpina* ×	20
Golden Gem	*Vitis aestivalis* ×	20
Black July	*Vitis aestivalis*	20
Lincoln	do	60
Merrimack	*Vitis labrusca* × *vinifera*	67
Opal	do	50
Goethe	do	40
Centennial	*Vitis aestivalis* × *labrusca*	40
America	*Vitis linsecomii* × *rupestris*	40
Early Market	(*Vitis vulpina* × *labrusca*) × *vulpina*	10

From the table it will be seen that varieties or hybrids of a number of species were susceptible to the disease. In the following list is given the names of those varieties or hybrids which remained free from the disease and are considered resistant, to some extent at least. Since there were, as a rule, not more than five vines of each variety, the small number must be taken into consideration as lessening the chances of infection.

The following varieties or hybrids of American grapes were free from disease:

Of the varieties derived from *Vitis labrusca:* Amanda, Arkansaw, Cambridge, Concord, Cottage, Eaton, Hartford, Illinois City, Ives, Martha, Moores Early, and Wyoming.

Of the varieties derived from *Vitis aestivalis:* Arkansas, Black Herbemont, Onderdonk, Muench, Mrs. Munson, Neva Munson, and Superb.

Of the varieties derived from *Vitis linsecomii:* Great Cluster and Lincy.

Of the hybrids of *Vitis labrusca* × *Vitis vinifera:* Barry, Black Eagle, Governor Ross, Herbert, Highland, Triumph, Campbell's Early, and Conqueror. Of *Vitis labrusca* × *aestivalis:* Gold Coin. Of (*Vitis labrusca* × *vinifera*) × (*aestivalis* × *vinifera*): Brilliant.

Of the hybrids of *Vitis linsecomii* × *aestivalis:* Admirable, Bumper, Delicious, Kemp, Hopkins, Hermann Jaeger, Marguerite, Oriole, Perry, and Vinita. Of *Vitis linsecomii* × *labrusca:* Beacon and Doctor Collier. Of *Vitis linsecomii* × (*labrusca* × *vinifera*): Bailey, Big Extra, Big Hope, Fern Munson, Long John, Newman, R. W. Munson, and W. B. Munson. Of *Vitis linsecomii* × (*aestivalis* × *labrusca*): Laussell. Of *Vitis linsecomii* × (*labrusca* × *vinifera*): Carmen. Of (*Vitis linsecomii* × *rupestris*) × (*labrusca* ×): Rupert.

Of the hybrids of *Vitis champini* × (*labrusca* ×)*:* Chambrill. Of (*Vitis labrusca* × *vinifera*) × *aestivalis:* Lindherbe. Of *Vitis vulpina* × *labrusca:* Ironclad and Taylor. Of *Vitis vulpina* × *aestivalis:* Bell. Of *Vitis vulpina* × *munsoniana:* Elvicand. Of (*Vitis vulpini* × *labrusca*) × *vinifera:* Rommell. Of *Vitis labrusca* ×: Moores Diamond, Peter Wylie, and Early Ohio.

Through the courtesy of Dr. Husmann, the writer was permitted to take notes on a large number of vines being tested by him in several localities in California for resistance to phylloxera and alkali. Through observations made in these and other vineyards in California, where vines are being grafted and grown on resistant stocks, it has been noted that where varieties like the Muscat of Alexandria, Mission, and others susceptible to crown-gall are grafted in stocks resistant to phylloxera there is often acquired a resistance to crown-gall.

A number of vineyards were examined in central and southern California in which the vines were grafted on Rupestris St. George and Lenoir and other stocks resistant to phylloxera. These were found to be almost free from crown-gall. Neighboring vineyards of the same age where the vines were grown on their own roots were found to be very considerably or even badly diseased. This gives still greater importance to the need of obtaining resistance by grafting in resistant stocks.

THE CAUSE OF CROWN-GALL.

The earlier investigators of crown-gall mistook the conditions of environment which favor the disease for its cause. The greater number of European observers have assigned the cause of the disease to physical agents, such as late frosts and winter killing. Among those who ascribed the cause of cane galls (Grind, broussin, etc.) primarily to injury received from freezing are Dornfield (15), Köhler (33), Du Breuil (16), Beinling (2), Goethe (28), Viala (55), Frank (21), and Sorauer (48).

Garovaglio and Cattaneo (23) and Dehors (13) thought that the disease might be brought about by injuries received from insects. In addition to the action of frost and injuries by insects, some investigators, according to these writers, have advanced the opinion that a superabundance of the food supply might favor the disease.

Von Thümen (58) found a species of Fusisporium in the galls and ascribed the disease to the action of the fungus, but did not prove its pathogenesis.

Corvo (11) in 1885 noted the presence of bacteria in the tubercles, or galls, on grapevines. Cuboni (12) in 1889 observed bacterial zoogloœæ in such galls and compared them with the bacteria in olive

knots. Comes (7) in 1891 thought that the disease was caused by *Bacterium gummis* and also the disease known as gummosis. Trevisan[a] named the organism as isolated by Cavara (5) *Bacillus ampelopsorae* n. sp. Cavara (5) claims to have proved the pathogenesis of this organism by inoculation with pure cultures.

Cooke (9) in 1893 described a disease on the roots of grapes much like the crown-gall. He asserted that he found a species of Plasmodiophora in the galls. This in 1903 he designated as *Plasmodiophora vitis* (10). He did not, however, prove the pathogenesis of the organism he found.

Woodworth (60) mentions the finding of a species of *Micrococcus* in grape galls which he grew in a pure culture, but he did not prove the pathogenesis of the organism.

Reddick (41) in 1909 described a fungus *Fusicoccum viticolum*, which he isolated a number of times from the cane galls of grapevines in New York. He ascribed the disease to this fungus.

The writer, in July, 1903, in a study of the disease at Bernalillo, N. Mex., found constantly occurring in the tissues of grape, cane, and root galls and in adjacent diseased tissues a motile bacterial species which was isolated repeatedly and grown in pure cultures in poured agar plates and slant agar tubes in a culture medium consisting of a decoction of celery added to McDougal's culture solution. In agar plates the colonies were round, with a smooth edge, whitish in color, and viscid when drawn out with a needle. No inoculations were made with the organism at the time. These cultures were lost in transit to St. Louis, Mo., where they were sent for further study.

Again, in July, 1904, a number of organisms, including five kinds of bacteria, were isolated from grape root galls. These were grown in pure cultures and inoculated in young Muscat of Alexandria and in Tokay grape seedlings. One of these organisms was in appearance similar to the one found in 1903, and of three Muscat of Alexandria seedlings inoculated with a pure culture of it two became diseased with galls at the point of inoculation. Wounded control plants remained healthy. Although the limited nature of the experiment rendered the results inconclusive, owing to the urgency of the immediately practical aspect of these investigations, this work was not prosecuted further at that time.

In April, 1907, Smith and Townsend (45) of the Bureau of Plant Industry, published an article describing a plant tumor of bacterial origin. They gave conclusive proof of the pathogenesis of the organism *Bacterium tumefaciens*, n. sp., which was isolated from the galls of the Paris daisy, grown in pure cultures, and studied. This organism, when inoculated into healthy plants of tobacco, tomato, potato, sugar beet, hop, and peach produced galls at the point of inoculation.

[a] Saccardo. Sylloge Fungorum, vol. 8, p. 983.

Wounded control plants of the same species remained free from the disease. This investigation established the relationship of a number of gall diseases and the cause of the crown-gall of the peach, etc. No inoculations were reported at this time on grapevines, but Doctor Smith informs the writer that one successful inoculation was made on the grape, April 3, 1907, and that 18 successful inoculations were obtained in May of that year (all that were inoculated).

During the first week in April, 1907, an organism similar to the one found in 1903 was isolated by the writer from grape root galls and inoculations were made into healthy peach, apple, and apricot seedlings during the second week in April. Of 14 peach seedlings inoculated 9 became diseased with galls at the point of inoculation; of 12 apricot seedlings 6 became similarly diseased; of 5 apple seedlings inoculated none became diseased. The final count was made on November 5, 1907. Wounded control plants of the same kind remained free from disease.

In December, 1908, at a meeting of the Botanical Society of America, Doctor Townsend (51a) reported the results of further experiments with the organism from the Paris daisy. This organism when inoculated into other plants produced galls on the tomato, potato, tobacco, sugar beet, hop, carnation, grape, raspberry, peach, and apple. This proves that galls on the grape may be produced by *Bacterium tumefaciens* and are identical in origin with those on a number of other plants. The galls obtained on the grape by Townsend were both on the canes and roots, and resembled in form the galls on the roots of the grape.

THE COMMUNICABILITY OF CROWN-GALL.

OBSERVATIONS BY OTHER INVESTIGATORS.

Very little has been published on the communicability of crown-gall, except in the line of opinions by observers. These will not be cited.

Lataste (34) communicated the disease to the root of a growing grapevine by binding a piece of living grape gall over a wound.

RESULTS OF EXPERIMENTS.

Experiments with seedlings.—In 1908 the writer (30) published the results of part of a series of experiments on the communicability of the crown-gall from a number of host plants, showing that the disease is communicable from pieces of living tissues of soft crown-galls placed in wounds on the roots of the host plants. These experiments proved the identity of the soft galls of the apple and pear with those of the stone fruits, raspberry, blackberry, and rose. A portion of these experiments was devoted to the communicability of the grape crown-gall. The results of these and other experiments will now be given.

Beginning with 1903 plants were grown each year from seed in the manner described on page 14. Some of these were inoculated at the age of from 3 to 6 months by inserting pieces of living grape root galls into wounds at or below the surface of the soil. Others were wounded without inoculations and set aside as a control. The results of these inoculations were negative in many instances. A summary of the results of these experiments for five years is given in Table IV. Both European and American varieties of grapes were used.

TABLE IV.—*Summary of the results of inoculating seedlings of various kinds of plants with grape crown-gall, 1903–1907.*

Kind of seedlings.	Inoculated plants.			Wounded plants.		
	Number of plants tested.	Proportion of healthy plants resulting.	Proportion of diseased plants resulting.	Number of plants tested.	Proportion of healthy plants resulting.	Proportion of diseased plants resulting.
		Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
Almond	34	91.2	8.8	62	100.0	0.0
Apple	21	100.0	.0	28	100.0	.0
Apricot	46	100.0	.0	80	100.0	.0
Blackberry	21	95.2	4.8	10	100.0	.0
Chestnut	10	100.0	.0	10	100.0	.0
Cherry	10	80.0	20.0	7	100.0	.0
Grape	262	85.5	14.5	358	99.7	.0
Peach	73	69.9	30.1	71	100.0	.0
Pear	5	100.0	.0	5	100.0	.3
Plum	14	100.0	.0	6	100.0	.0
Raspberry	50	96.0	4.0	125	100.0	.0

The results of the experiments prove the communicability of the grape crown-gall (14.5 per cent) with pieces of galls. They also show that the disease is communicable as follows: To the almond, 8.8 per cent; blackberry, 4.8 per cent; cherry, 20 per cent; peach, 30.1 per cent; and raspberry, 4 per cent. The inoculations on the apple, apricot, chestnut, pear, and plum gave negative results.

Another set of experiments was conducted similarly with grape seedlings, except that the inoculations were made with galls from other host plants. Table V shows the results:

TABLE V.—*Summary of the results of inoculating grape seedlings with galls from other host plants.*

Galls taken from—	Number of grapevines inoculated.	Proportion of healthy plants resulting.	Proportion of diseased plants resulting.
		Per cent.	*Per cent.*
Almond	8	100.0	0.0
Apple	81	100.0	.0
Blackberry	38	100.0	.0
Peach	44	93.2	6.8
Pear	13	100.0	.0
Plum	18	100.0	.0
Raspberry	52	92.3	7.7
Rose	57	97.3	2.7
Control	359	99.7	.3

The results from this experiment do not differ radically from the former as regards hosts. They indicate the communicability to the grape from the following hosts: Peach, 6.8 per cent; raspberry, 7.7 per cent; rose, 2.7 per cent. No communicability was shown in the cases of the galls from the almond, apple, blackberry, pear, and plum.

A third set of experiments was conducted in the greenhouse with apparently healthy pear seedlings selected from nursery stock, which were washed clean and inoculated with pieces of crown galls from the roots of grape and other host plants. The results are given in Table VI:

TABLE VI.—*Summary of the results of inoculating healthy pear seedlings with grape and other galls.*

Galls taken from—	Number of pear trees inoculated.	Proportion of healthy plants resulting.	Proportion of diseased plants resulting.
		Per cent.	*Per cent.*
Almond	93	96.8	3.2
Apple	379	99.2	.8
Blackberry	200	91.0	9.0
Cherry	100	83.0	17.0
Grape	387	99.2	.8
Peach	293	78.2	21.8
Pear	83	100.0	.0
Raspberry	197	93.4	6.6
Rose	173	90.2	9.8
Control	196	99.5	.5

The results of the experiment show that the disease is communicable to pear seedlings from other host plants as follows: Almond, 3.2 per cent; apple, 0.8 per cent; blackberry, 9 per cent; cherry, 17 per cent; grape, 0.8 per cent; peach, 21.8 per cent; raspberry, 6.6 per cent; rose, 9.8 per cent. Negative results were obtained again with the pear, also with the apple and grape, on account of the fact that the control plants were diseased in almost the same amount.

The results of these experiments indicate that the crown-gall is communicable to some extent from the grape to the stone fruits and blackberry and raspberry, and vice versa. The degree of communicability to the apple from the grape appears to be almost a negligible quantity.

Experiments with older vines.—The earlier investigators who assumed that freezing, injuries, etc., were the cause of crown-gall erred, but in doing so found the conditions that favor the communicability of the organism causing it.

The cause of the disease can not be ascribed to injuries due to freezing, since the disease is found on plants grown and inoculated in the greenhouse at temperatures far above freezing. Wounds are apparently necessary for the entrance of the organism causing the disease, and freezing produces wounds. Cane galls were observed

forming in injuries to vines caused by late frosts at Bernalillo, N. Mex. They were also noted forming in wounds received by cultivation and in those due to pruning. The pruning knife apparently may disseminate the organism.

In a vineyard under the observation of the writer at Bernalillo, a virgin piece of soil was leveled and planted with Mission vines of the New Mexico variety. These were placed on a terrace slightly lower than an older vineyard containing the badly diseased vines of an earlier planting. The new vineyard was planted with healthy vines grown from cuttings taken from healthy vines. The vines grew well and all remained healthy for a year. Then a careless workman who was irrigating by surface irrigation allowed the water to break through a ridge and flow directly from the old vineyard across the center of the new one. The following year the vines in the overflowed portion of the new vineyard became diseased. The fourth year the disease had spread by irrigation to all portions of the vineyard.

In central California it was noted that vineyards that were subirrigated showed little crown-gall, but those of the same varieties in adjacent vineyards that were surface-irrigated showed much of the disease in all portions of the vineyards.

Bees probably communicate the disease as carriers of bacteria found in the galls and the adjacent diseased tissues. In the spring they were observed feeding on the exuding sap after the vines were pruned and then passing from diseased vines to healthy ones.

That the disease can be communicated by means of diseased cuttings has already been shown by the results of the experiment previously described in this bulletin.

THE CURE OF CROWN-GALL.

NEGATIVE RESULTS FROM EXPERIMENTS WITH FUNGICIDES.

As stated on a previous page, the experimental plat at Bernalillo, N. Mex., originally was planted with about 5 acres of grapevines of the Mission (California) variety, and these became badly diseased. All the diseased vines were treated as follows in the spring of 1903 to control the disease: The ground was removed from the base of the vines and all the galls cut away; then the wound was covered with a paste made of copper sulphate and lime.

Some of the vines were probably killed by this treatment, but the disease was not checked, as galls broke forth anew from the vines on other portions of the plants.

The following autumn a portion of the vineyard was again treated as follows: The vineyard was divided into blocks of five rows of 60 vines each. On three adjacent rows of vines about equally diseased

the soil was removed around the base of the plants, the galls removed by excision with a sharp knife, and the wound washed with a fungicide. The galls were cut from the vines in an adjacent row, but no chemicals were applied. This row served as a wound control. On a fifth row of vines the galls were undisturbed, as a further control to treatment by excision and by the use of fungicides. This block of five rows made an experiment.

Several such blocks were similarly prepared and three rows treated in each, using the following water solutions of chemicals, a different one in each block: (1) A 2 per cent solution of copper sulphate; (2) a 5 per cent solution of iron sulphate; (3) a 2 per cent solution of formalin. In a fourth block the wound was covered with powdered sulphur. Four more blocks were given the foregoing treatments except that each plant received in addition an application of a fertilizer containing bone phosphates and nitrate of soda.

During the winter which followed many vines in all of the rows died, and of those that lived none certainly recovered. The rows treated showed no improvement over the others. The experiment resulted so badly that the vines were removed and replaced with other varieties in an attempt to secure resistant varieties. Although these experiments failed to accomplish the cure of the diseased vines they can be considered only as indicative of the probable futility of curing the disease by excision of the galls followed by the application of a fungicide. They do not prove the impossibility of a cure by some other method of surgical or chemical treatment.

THE PREVENTION OF CROWN-GALL.

The results of the studies and experiments with the disease indicate the necessity for prevention rather than cure. This can be accomplished either by the use of resistant vines or by grafting nonresistant vines on resistant stocks.

RESISTANT VINES SHOULD BE PLANTED ON THEIR OWN ROOTS.

In the experiment previously described, where 24 of the best varieties were grown in infected soil to test their resistance to attacks by the disease, it was found that a number of varieties were quite resistant to crown-gall, as follows: Rupestris St. George, Feher Szagos, Sweetwater, Golden Chasselas, Seedless Sultana, Carignane, Grenache, Gros Colman, and Mataro. These varieties will succeed well on their own roots. More than a hundred varieties are being tested by Prof. Fabian Garcia, of the New Mexico Agricultural Experiment Station, in an experiment begun in 1904 in cooperation with this Bureau but now being completed by the station. An

additional number of resistant varieties will be determined from this experiment.

RESISTANT STOCKS SHOULD BE USED FOR GRAFTING NONRESISTANT VARIETIES.

The Rupestris St. George variety gave the highest degree of resistance to the disease and grew vigorously. This variety is of no value except as a stock for the purpose of bench grafting. Its resistance to the disease being very high makes it a valuable vine for this purpose. Its resistance to the phylloxera makes it doubly valuable, since sooner or later this pest will be likely to appear in every vineyard region where European varieties of grapes are grown.

The Lenoir variety, used as a stock for grafting, is also valuable as a wine grape. Although quite a number of vines of this variety became slightly diseased in the experiments, none were seriously affected, and it is recommended as a good vine for the Southwest wherever the crown-gall has appeared, either when grown for its fruit or as a stock for ingrafting more susceptible varieties. It is not within the province of this bulletin to enter fully into the discussion of all the varieties of vines resistant to the phylloxera, most of which will very probably be found resistant to the crown-gall.

In localities where the ravages of the disease are marked, it is not advisable to plant the Mission variety, especially the Mission from California, the Muscat of Alexandria, Flame Tokay, Rose of Peru, Malaga, Burgundy, or Riesling varieties unless grafted upon resistant stocks.

OTHER MEANS OF PREVENTION.

When vines are grown from cuttings, care should be taken to secure cuttings from vineyards free from the disease. Such cuttings should be grown in soil where vines have not been grown for five or more years.

In planting vines or cuttings in the arid regions it is best to plant them deeply, so that not more than one bud or eye will remain above the soil. This will protect them both from freezing and from the burning sun, both of which are injurious to the young vines and lower their vitality even though an entrance of the disease may not take place.

In case a vineyard or locality is free from crown-gall it is best to be exceedingly careful where vines are purchased for planting. That the nursery is free from the disease should be ascertained before purchasing varieties of European grapes. It is better, where possible, to propagate vines by bench-grafting on healthy stocks grown at home from cuttings selected from healthy vines.

SUMMARY AND RECOMMENDATIONS.

The disease of grapes in this country designated as black-knot, crown-knot, root-knot, crown-gall, and as root tumors has been known for many years. In Europe it has been known for a longer period as "Grind," "Kropf," "broussins," "rogna," "tuberculosi," etc.

Two forms of the disease occur commonly on varieties of *Vitis vinifera* in the southwestern and western United States. One form occurring as rough, often hard, excrescences on the canes of grape-vines is designated as cane galls in this bulletin and is also known as "black-knot," "Grind," "broussins," "rogna," etc. (Pl. II, fig. 2.) The other form, occurring at or below the surface of the ground on the crowns and roots of the vines in the form of soft galls, is designated as root galls in this paper, but is also known as "tumors," "Kropf," "rogna," and "tuberculosi." (Pl. III, fig. 1.)

The crown-gall, or a similar disease, is widely disseminated in many parts of the world, especially where varieties of *Vitis vinifera* are grown.

The entrance of the disease in vines is favored by injuries, such as those due to freezing and late frosts, to pruning, etc. The effect of the disease is very destructive, often killing or stunting nearly all the vines in a vineyard in a few years, resulting in a heavy loss in many localities, especially in the western United States.

The galls usually develop annually, rotting away at the end of the growing season, the rot killing the adjacent tissues and cutting off the circulation of the vine, having much the effect of a cancer.

A great variation in the resistance to the disease is shown by many varieties of European and American grapes. Of European grapes the Muscat of Alexandria and the Mission of California were found to be the most susceptible varieties. No species of *Vitis vinifera* was found to be entirely immune. Some hybrids with American varieties possess a high degree of resistance. Among these are the Rupestris St. George and other similar varieties. The Lenoir possesses a high degree of resistance and is in many ways desirable as a grafting stock.

In New Mexico the varieties found most resistant were Feher Szagos, Sweetwater, Seedless Sultana, Carignane, Grenache, Gros Colman, Mataro, Black Malvoisie, Burger, and Lenoir. These vines are more or less resistant on their own roots and are recommended for planting in infected vineyards. A higher resistance to the disease can be obtained by grafting these or other desirable varieties on such stocks as the Rupestris St. George and the Lenoir, which are also resistant to phylloxera.

The disease is communicated in a number of ways: (1) By the water of irrigation; (2) by cuttings from diseased plants; (3) probably by the pruning knife; and (4) by insects.

As a protection against frost injuries, cuttings or young vines should be planted deeply in the soil, especially in arid regions, allowing only one bud to project above the surface of the ground.

Cuttings and young vines should be secured from healthy surroundings. It is better to use vines grown under one's personal supervision than to purchase from a vineyard or nursery known to be infected with the disease.

Grapevines should be pruned in the spring either before or just after the period of sap flow, the time varying with the locality. They should be protected in winter from freezing where necessary, and the protective covering should not be removed until the danger of injury is passed, because the wounds produced by late frosts afford a means of entrance to the organisms causing the disease.

Finally, in a new vineyard resistant vines should be planted if possible. If it is necessary to grow nonresistant vines they should be grafted on stocks that are resistant. All diseased vines should be burned as soon as they are discovered and replaced with healthy resistant vines.

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PLATES.

DESCRIPTION OF PLATES.

PLATE I. *Frontispiece.* A 4-year-old Mission grapevine from the experimental vineyard at Bernalillo, N. Mex., badly diseased both above and below the surface of the ground. The young offshoot is the result of an attempt on the part of the vine to renew itself.

PLATE II. Fig. 1.—A 4-year-old Muscat of Alexandria grapevine from the experimental vineyard at Bernalillo, N. Mex., badly diseased with confluent root galls. Fig. 2.—Another Muscat of Alexandria grapevine from the same lot as that shown in Figure 1 diseased with confluent root galls below and cane galls above.

PLATE III. Fig. 1.—Root galls on a badly diseased Flame Tokay grapevine from the same vineyard as those shown in Plate II. (One-third natural size.) Fig. 2.—A Muscat grapevine diseased with a globose gall, resulting from an inoculation.

PLATE IV. Fig. 1.—View of a portion of the experimental vineyard at Bernalillo, N. Mex., before the diseased Mission vines were replaced with other varieties. Fig. 2.—A view of a portion of the experimental vineyard at Bernalillo, N. Mex., after it had been planted with resistant vines.

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FIG. 1.—A MUSCAT OF ALEXANDRIA GRAPEVINE DISEASED WITH CONFLUENT ROOT GALLS.

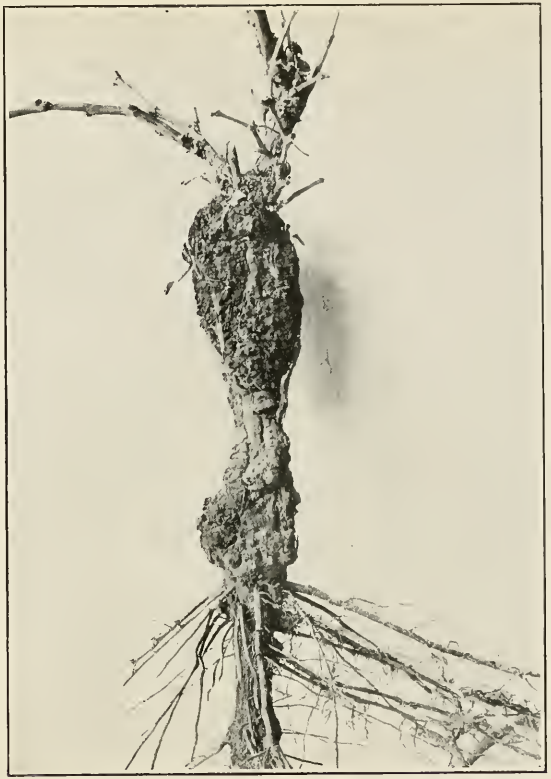

FIG. 2.—A MUSCAT OF ALEXANDRIA GRAPEVINE DISEASED WITH CONFLUENT GALLS ON BOTH THE CANE AND ROOT.

FIG. 1.—A FLAME TOKAY GRAPEVINE DISEASED WITH GLOBOSE ROOT GALLS.

FIG. 2.—A GLOBOSE ROOT GALL ON A MUSCAT OF ALEXANDRIA GRAPE SEEDLING.

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FIG. 1.—A PORTION OF THE EXPERIMENTAL VINEYARD AT BERNALILLO, N. MEX., SHOWING DISEASED MISSION GRAPEVINES.

FIG. 2.—A PORTION OF THE EXPERIMENTAL VINEYARD AT BERNALILLO, N. MEX., AFTER IT HAD BEEN PLANTED WITH RESISTANT GRAPEVINES.

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